TECHNO-SUBJECTIVITIES:

THE ARCHITECTURE OF SUBJECT FORMATION AND THIRD-THUMBS

This dissertation has been written and submitted to fulfil the requirements of the Doctor of Philosophy.

by

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Authors Declaration

This is to certify that the content of this thesis is my own work. This thesis has not been submitted for any other degree or purpose.

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Abstract

This research explores how the *technics* of the third-thumb intersects with philosophical theories of subjectivity and architectural thinking. This thesis asks: *What happens when we stop seeing technology as separate from who we are?*

This research explores subjectivity as a dynamic process shaped by bodies, technologies, and social forces. Drawing on Félix Guattari's and Suely Rolnik's *The Molecular Revolution in Brazil* (2008). I argue that prosthetic augmentation—such as the augmentation of a third-thumb—is not just a tool but a *machinic assemblage* that can break hierarchies and liberate desire. Through the idea of *transversality*, technology becomes a catalyst for freedom and inclusion, transforming not only the body but also architecture as an ethical and aesthetic practice.

There are two points of gravitation here. The first examines a very particular idea of subjectivity, drawing primarily on Guattari and Rolnik's ideas on *subjectivity.* This is a very complex and specific idea that radically alters previously held ideas about how subjectivity is produced. The second is the idea of prosthetic augmentation, that is, the addition or supplementation of a digit to the hand, something akin to a third thumb.

Thus, the two ideas of subjectivity and its relationship to the *technics* of an augmented prosthetic third-thumb become deeply entwined. The research examines the interplay between philosophical and psychoanalytic explanations of how subjectivity is formed within a technological milieu and its relation to socio-political and economic discourse.

Rather than treating technology as external to subjectivity, this thesis argues that the third-thumb functions as a *machinic assemblage* participating in what Guattari terms the 'production of mutant subjectivities.'[1] The investigation operates across interconnected registers: the philosophical-psychoanalytic mechanisms of subjectivation, the socio-political and economic assemblages that frame these processes, and the architectural implications of prosthetically-augmented corporeality.

I will argue that the third-thumb or the prosthetic supernumerary robotic finger (SRF) becomes part of a theory of *machinic assemblages* that inculcate itself into the unconscious of subjectivity using a theoretical idea of *transversality*: that is a psychoanalytic and operational tool that enables cross-connections between heterogeneous elements in thought, action, imagination, and ideation—across

[1] Suely Rolnik; Félix Guattari, *Molecular Revolution in Brazil*, trans. Karel Clapshow; Brian Holmes, 2008 ed., vol. 1 (Semiotext(e), 2008), p454.

institutional structures, social fields, subjective formations, and disciplinary boundaries—without reducing their specificities. Through engagement with concepts such as the *molecular revolution*, transversality, and the formation of heterogeneous subjectivities, this research demonstrates how the third-thumb participates in broader processes of technological subjectivation, which can reshape social-political conditions and their environmental and spatial implications. The thesis examines how prosthetic technologies function not merely as functional augmentations but as existential territories that generate new forms of affect, perception, and spatial relations.

The outcome reveals the fundamentally interrelated nature of human, technological, and architectural assemblages. There is a quiet idea running deep through this dissertation that gives perspective on how we think about architecture. And this idea comes to the fore at the end of the thesis, when, after considering all the ideas, we can see the direct relationship of architecture to the body, its scale, its movements, and its psychoanalytic patterns. If the body and its extensions are active agents in shaping architecture, then architecture must move beyond static forms to become part of a fluid, ethical, and aesthetic network.

This research proposes that prosthetic augmentation catalyses transformations in spatial perception and architectural possibility that exceed purely functional considerations, ultimately arguing for understanding prosthetic technologies as active participants in the ongoing *molecular revolution* of subjectivity (and its ensuing socio-political change). *Techno-subjectivities* thus require new approaches to architectural thinking that accommodate multiplicitous and mutant forms of embodiment within contemporary techno-social assemblages.

As Guattari writes, '[i]Informatic subjectivity distances us at high speed from the old scriptural linearity'.[2] In the context of this dissertation, this may suggest that, in the realm of *techno-subjectivity*, we are being encouraged to move toward new modes of design that embrace multiplicity and transformation.

Ultimately, this work proposes that modes of *technics*, such as the third-thumb, catalyse social modes of thought by changing how we think about architecture, inviting us to imagine futures in which design, technology, and subjectivity evolve together.

[2] Félix Guattari, *Chaosmosis and ethico-aesthetic paradigm*, trans. Paul Bains; Julian Pefanis (Sydney, Australia: Power Institute Foundation for Arts & Visual Culture, 2006), p96.

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Chapter 1 - Introduction

Background

This work engages post-structuralist thought to traverse a constructivist application. The methodology is one I have been negotiating for some time and that relates to my background in architecture and architectural theory. Henceforth, I explore a series of relationships that interlace ideas relating the body and mind to architecture through a particular characterisation of technology and its impact on subjectivity. At the same time, the social, political, and economic threads that bind technology and subjectivity together are also used to reconsider the body's relationship to wider fields. This entanglement is significant because it leads to a particular stance towards architecture itself, which may prompt a reconsideration of its importance to modern societies and its inseparability from the subject and all its environmental relations, including political, economic, and social aspects. When I speak of the environment, there are no clear delineations between the various aspects of life here. This aligns with the ideas presented by the authors, psychoanalysts, and concept-makers that form the central tenets of this dissertation. I shall particularly engage the ideas of Suely Rolnik and Félix Guattari and their theories of subjectivity detailed in their complex (and at times perplexing) book *Molecular Revolution in Brazil* (2008) to explore the augmentation of a prosthetic, referred to in the literature as a 'Supernumerary Robotic Finger' (SRF) (also referred to in some instances in this dissertation as a 'third-thumb') to develop and extend the intersectionality of subjectivity and technology. This is the focus of the work. It is worth noting, however, that this focus departs from and returns to my own reflections on architecture.

However, I would like to start by noting how I came to discover the connections between the body, technology, and socio-political and economic events that have shaped me and my interest in architecture. It began in the very formative years of my early childhood development, between the ages of three and five, when the refrains of my earliest memories led me recursively. These memories shuttle back and forth to the moment at age eight when the disjunctions in my life came to shatter my idyllic childhood, only to witness the savagery of war, revolution and the effects of familial trauma. As a child, adrift in a moment lost in time, besieged by the feeling of abandonment as a father escaped for political refuge, leaving a mother to defend us from guns and bombs and the trauma of war and revolution. The scars are ever-present, leaving me to regress and retreat, nearly five decades later, into childhood to relive the lost memories of a happy, later frightening, childhood and the inability to reconcile the trauma of those events that ensued. The traumatised child is a

constant ghost that haunts the adult me every day since then. Still, my mind's eye holds the picture of home dearly, which soon came to represent a little fine Fabergé egg containing precious, happy little jewels—the only happy moments of my childhood. These alluring memories drive me towards recuperation and reconciliation in all future relations with objects and subjects, and indeed, with architectures.

From the early to late 1970s, until I was eight years old, I lived in a modest modernist, architecturally designed international-style home with white walls and glazing, and floors clad in travertine and marble, in the affluent suburbs of Tehran. The neighbourhood of Saltanat Abad (سلطنت آباد), meaning "built by the monarchy," referred to as the palace of the Shah (Mohammad Reza Pahlavi), is situated at the northernmost tip of its vicinity. This mirage of paradise lost was built on the enthusiasm of the Iranian Shah and the Pahlavi Dynasty's drive to modernise Iran and Iranians, led by Mohammad Reza Pahlavi. The home's interiors were filled with objects from around the world, reflecting its modernist aspirations. The eclectic choice of bourgeois *objets d'art* was aesthetically astounding for a small child who marvelled at the array of materials, colours, shapes, and textures. Walls were adorned with ink sketches and paintings from France, artifacts from East Africa, English Victorian silverware, fine Indian gold filigree dessert plates, and Italian porcelain chandeliers. The marble floors were lined with a dazzling array of unique Persian rugs from all regions, featuring bright colours inlaid with silk. These rugs, arts, and crafts represented my mother's nationalist intensity and devotion to her country, culture, people, histories, and texts. They connected her to her broader geohistorical family roots, trials, and tribulations, which are deeply embedded in the subjectivity and collective unconscious of her people.

Our daily interaction with high-tech objects of the latest fashion reflected the revolutionary, machinic future envisioned in their architecture. My father designed the Shah's military satellite communication technologies. He was a partner in an Anglo-American technology company that provided technology to the military, so getting the latest tech demonstrated our commitment to the Shah's vision. Through the expansive glass envelope, the interiors looked out to a Persian-style rose garden, awash with a kaleidoscope of colours, set in a traditional Persian parterre or char bagh (four-leaf) garden. The scent of lush rose bushes that climbed the internal walls of its courtyard perfumed the house when the cool winds blew down from the tops of the Alborz mountains, the backdrop to the house. The vast, elevated snow-tipped mountains provided a cool relief that subdued the hot, desert air of the long summer days. The polychromatic petals—yellow, crimson, pink, and violet—sprayed out like falling confetti into the ornate Persian-style turquoise, traditionally glazed haft-rang Kashi Kari (the seven-coloured Persian tiles of Shiraz) bordered reflection pool, deep enough to double as a swimming pool. Its central fountain and its babbling resonances created water vapour

that blew about, creating a cool, misty air. Spaces for my childhood daydreams reflected off the deep aquamarine pool surface. The water and its lush greenery were central focal points that drew the eye to the contradiction of this vocabulary that mixed the old and the new. It symbolised the political struggles of a nation in tension, its rich culture, and often complex, tumultuous history. A history that was always foreshadowed by nations seeking to conquer it, forging a collective identity that produced great art and poetry, as well as a distinct Oriental identity of resistance.

The modern white and glazed walls of the villa, styled after the aspirational Qajar palaces, albeit on a modest scale, with its ornate traditional garden, represented the juxtaposition of strains reflecting its current political turmoil. This turmoil was about to bring a nation to its feet with revolutionary fervour rising from its populace's indignation at its unpopular Shah. The same indignation brought men with Kalashnikovs into our home, holding us ransom, angry and envious, aggrieved by the injustices of a regime that bred inequity.

The trauma of loss and the abandonment of this modest building became the point of contestation and then a mental palace and, at the same time, a prison of memories that still persist. Although the house is no longer there, its lasting memory leaves me conflicted by an expression of architecture that represents a divisive, elitist, and out-of-touch view of modernism, one that ignored the struggles of a repressed nation in its drive to emerge from the complex tensions with its obstinate Islamic past. Yet it was my home, and my Fabergé egg remains my mental palace. This architecture engendered a type of design discourse that spoke of discordance with its awkward clashing relation to the politics of its international and vernacular aesthetics. The impact of its relation to the built environment, its connection to modern Iranian life, and its historical context during the time it was built —the 1970s —would come to shape my memories into adulthood, prompting me to ask how I could have been so blind to the suffering of others. But I was only a child.

I have always been interested in the body and architecture, and my own journey over the past decade, both retraining in architecture and undergoing intense psychoanalysis, brought me to this point of exploring how my own subjectivity was influenced by art and technology. It is not only the profound upheaval of my early life that has left me with fractured memories, but also the way it has ultimately forged how I think about architecture. These memories are more than nostalgia; they colour and mediate all that I see and shape all my relationships with objects and architecture from the past into my current intellectual trajectory. In my teenage years and into my early twenties, my first experience of architecture came when my parents put me in charge of building us a new family home. My parents were working hard to get us past the trauma of Iran while reestablishing ourselves in Sydney, Australia, as far as possible from the chaos of the Iranian revolution. It soon

became really obvious the importance of architecture as a deeply psychosocial endeavour that anchored me and my family in totally new ways, as well as helped us recover a sense of self as we all navigated a new social and political system, while we also experienced a profound change in our technological life. As we mentally stabilised our lives and worked to rebuild them in the late 80's and 2000's, we were also experiencing a technological revolution in telecommunications and computing. My father worked in telecommunications and technology innovation for Telecom Australia; he helped launch the first mobile phone. I was studying molecular biology (genetics) at the University of Sydney when technology was helping map the human genome. We were studying the great discoveries in our understanding of the human genome as discoveries became live and part of the curriculum. These were interesting times.

When I left university, I started working in the telecommunications industry, focusing on high-end ICT systems. I worked in transformative mobile technologies from the 1990s through the boom and bust of the 2000's. I witnessed firsthand how technology reshapes lives. This experience deepened my interest in how we allow ourselves to be transformed by machines. This new type of revolution had captivated me. I recall I was working for Vodafone Australia at the time, and we had a benign feature on the network that allowed people to send text messages to one another. We had no idea what benefit this would provide to people, but we flicked on the switch and permitted this function. Within three weeks, we experienced an overwhelming amount of traffic on the networks. This text messaging system was taking off, and we soon started charging people for it. Very rapidly, we watched a total transformation in how people communicated. Twenty-five years later, when I read about the idea of *molecular revolutions*, the concept Rolnik and Guattari use to describe small, processual changes that can transform societies from within, rather than major schisms that involved bloodletting, like in the Iranian Revolution, their ideas inspired me to think about how technology might catalyse similar shifts: breaking hierarchies, liberating desire, and opening new territories for minorities and marginalised groups.

In this dissertation, I examine the complex intersections of technologies and subjectivities, as well as the ways in which our contexts shape us. The ideas of psychoanalyst Félix Guattari, his post-structuralist ideas and positions on subjectivity and the psyche, are engaged to examine the augmentation of the body with a prosthesis of a third-thumb or Supernumerary Robotic Finger (SRF) as a type of echo to reproduce and replay my relationship between the changing and alternative social and political paradigms. It would not be the Iranian Revolution, though, to which I turn; instead, the ideas in Rolnik and Guattari's *The Molecular Revolution in Brazil* (2008)[3]. Rolnik and

[3] Guattari, *Molecular Revolution in Brazil*, 1.

Guattari's work explores and probes contentious ideas about how closely architecture and the body's design ontologies are intertwined through augmentation with an object. The ideas relate not only to the built environment but also encompass its broad social, political, and economic environmental issues, which are intimately linked to individual and collective subjectivity. Through this reconsideration, I explored how architecture and its design morphologies help reformulate the project of subjectivity, not just a passive structure that shelters the body, but rather an expansive engagement for its conservation to elaborate life, free will, autonomy, and flourishing subjectivity via an ethical and aesthetic force that liberates desire.

I would like to point out that, although this dissertation builds upon the ideas of Rolnik and Guattari as presented in their book, *Molecular Revolution in Brazil*, I will often make references to Rolnik or Guattari separately, or together, due to the book's format and complexity. The book was a work curated by Rolnik and written by her. However, the journey she recounts echoes dialogue from Guattari and herself, amongst many others, but is predominantly based on the concepts and ideas that Guattari has developed. Therefore, Rolnik says in her preface to the book 'THIS BOOK WAS NOT JUST WRITTEN with four hands. Many more were involved'.[4] For this reason, the dissertation directly references Guattari and his other works, but does not neglect Rolnik; rather, it attempts to clarify which voices articulate which ideas in the book. Guattari graciously hands over the authorship of the book and its ideas to Rolnik, but the fact remains that the book is an assemblage of Guattarian concepts, a life-work understanding of psychoanalysis, and a polymathic and philosophical perspective. In the 2008 edition of the book used for this dissertation, Rolnik placed a text written by Guattari on the back cover of the first Brazilian edition before the preface. It reads:

> Before being a work on philosophy, psychoanalysis or politics, this book is a kind of travel journal. Suely wrote it after the trip that she and I made across Brazil, looking for individuals and groups as well as being found by intensities and desires along the way. These fragments, blocks of ideas, pieces of conversations, letters, debates, conferences, confidences—montages that Suely has made of statements by me, by her, by many others—are then a break with the bonds of the individualization of enunciation. They are, I would say, a love at first sight with the collective intelligence and sensibility of this country [Brazil]. — Félix Guattari[5]

[4] Guattari, *Molecular Revolution in Brazil*, 1, p15.
[5] Guattari, *Molecular Revolution in Brazil*, 1, p3.

Aim and abstract

This dissertation has one aim, and that is the exploration of the intersections between Rolnik and Guattari's psychoanalytical theories of subjectivity and the field of Supernumerary Robotic Finger (SRF) research, with particular attention given to the augmentation of a third-thumb. The affordances of this framework provide an understanding of human-machine interaction through the augmentation of *machinic* technology, which has a ripple effect on the various broader environmental economies that encompass it. The study seeks to reframe prosthetics beyond compensatory functions toward *techno-subjectivity*, emphasising their role in shaping identity and social relations. Using Rolnik and Guattari's book *Molecular Revolution in Brazil* (2008), supported by several other Guattarian texts, the dissertation works through the various ideas that undergird Guattarian thought to uncover those ideas of subjectivity that are simultaneously linked to the body, mind and its environmental context (social, political, and economic). For Guattari, subjectivity is not an individual, fixed entity but rather a dynamic, collective, and *machinic* process (a processing circuit of constant connections between dynamic complex autopoetic systems he prefers to call *machines*). Guattari moves beyond traditional psychoanalytic and philosophical views of subjectivity, which are often tied to personal identity, interiority, or consciousness. His critique suggests that subjectivity in today's society is 'essentially manufactured, modelled, received, and consumed'[6] from the various terminals of capital, the media and other such habitual hegemonic structures (hierarchies) that control the unconscious and its subjectivities. Instead, he sees subjectivity as something produced through multiple, interconnected processes—social, machinic, economic, semiotic, and political. Guattari suggests, 'I always prefer to speak of subjectivation, or the production of subjectivity'.[7] This is because subjectivity isn't a *given*; it is a factor of various forces *coming together,* a combination of push and pull that is not internal but rather an interaction between internal and external forces that intertwine the social, political, and economic. To clarify, Guattari is articulating a critical shift in how we should understand the production of subjectivity within modern capitalist and industrial societies. Traditionally, subjectivity—how individuals and collectives perceive themselves and their place in the world—was often viewed as a *superstructure* shaped by society's more fundamental economic and material base (in Marxist terms).[8] It was believed that subjectivity was largely a reflection or byproduct of existing social relations and economic structures, a secondary effect of material conditions. However, Guattari challenges this view by arguing that subjectivity should be understood as a primary and productive force in its own right, 'the raw material of the evolution of

[6] Guattari, *Molecular Revolution in Brazil*, 1, p35.
[7] Guattari, *Molecular Revolution in Brazil*, 1, p35.
[8] Guattari, *Molecular Revolution in Brazil*, 1, p36.

productive forces'.[9] He claims that the production of subjectivity is not merely dependent on the economic structures of society (i.e., it's not just shaped by how goods are produced, exchanged, and consumed), but is itself a raw material that actively participates in the evolution of society's productive forces. Rolnik and Guattari come to tie the production of subjectivity to the emerging fields of telecommunications, computers, robotics, and media. They suggest that these technologies are not just tools for production but also directly affect the way subjectivity is constructed and lived. The growth of these technologies means that subjectivity (the way we perceive ourselves, interact with others, and understand the world) is increasingly shaped by technological systems. They offer this reflection:

> This is the raw material [referring to subjectivity] of the very movement that is animating the current world crisis, a kind of will for productive power that revolutionizes production itself through scientific and biological revolutions, through the massive incorporation of telecommunications, computers, and robotics, and through the increasing weight of collective facilities and the media.[10]

Guattarian subjectivity is constantly being redefined and transformed by its relationships with other forces and is deeply intertwined with the collective and the external world. Guattari's theory of subjectivity shifts the focus from the individual to the assemblages of relations that generate new ways of being.[11] For him, subjectivity is not only shaped by internal psychological processes but also by external forces, such as technology, social institutions, and environmental conditions. Subjectivity is always in motion, produced through assemblages and continually evolving through processes of *becoming*.[12] Thus begins the investment in understanding the various concepts that define this project of subjectivity. This dissertation will review and follow the themes that help us understand what the two psychoanalysts mean by subjectivity and how it relates to the field of SRF.

When examining the field of SRF, I will define the various challenges confronting SRF researchers to identify the intersections that involve these projects in the field of subjectivity. Through my survey and examination of the most recent and comprehensive set of papers on the nascent field of SRF over the past decade and a half, I will offer a theoretical perspective on how Guattarian ideas can benefit the field. Through the Guattarian psychoanalytical and sociological gaze, I offer a reappraisal of how the field of SRF can foster a more open practice of innovation and creativity. By looking at particular instances and particular SRF projects that buck the trend of institutional habits (that often

[9] Guattari, *Molecular Revolution in Brazil*, 1, p36.
[10] Guattari, *Molecular Revolution in Brazil*, 1, p36.
[11] Guattari, *Molecular Revolution in Brazil*, 1, p43.
[12] Becoming is a process of self-actualisation that is realised through the unconscious that processes the inner self interacting with external forces to produce subjectivities.Guattari, *Molecular Revolution in Brazil*, 1, p396.

eschew subjectivity) in the field of SRF, I highlight how the field can progress and might achieve the objectives it (itself) asserts.

The third-thumb and its variants as SRFs are dealt with systematically in this dissertation. Although this is a lengthy and arduous process for the reader, it is necessary to review each edifice to understand how it contributes to the discourse. SRFs come in many forms and are part of a larger category of Supernumerary Limbs (SRLs).[13] The focus of the dissertation and its scope of study will remain SRFs only. I should note, however, that many papers to be examined will group SFRs under SRLs and refer to them accordingly, due to the commonalities in some features of their technical issues and aspects of the research conducted. Therefore, wherever possible, the dissertation attempts to separate the SRF literature from the entanglement with SRL literature to enhance clarity. Readers should not be alarmed or confused if they encounter SRLs in quotations that highlight broader issues related to SRFs. The interchange of SRLs as the broader encompassing field means that the issues being discussed refer to both and are centred on SRFs. Tong et al. give their introduction to the world of SRLs in this way:

> Supernumerary robotic limbs (SRLs) are a new type of wearable human auxiliary equipment, which is currently a hot research topic in the world. SRLs have broad applications in many fields, and will provide a reference and technical support for the realization of human-robot collaboration and integration, while playing an important role in improving social security and public services.[14]

Such lofty aspirations are rarely followed through into the research discussion and commentary in SRF literature. Before addressing issues such as their social effects and understanding the importance of SRFs to broader political issues, many become fixated on product development and scientific problematics, hence losing sight of the issues that relate to the user and their subjectivity. Many view their role as engineers and scientists as one that necessarily excludes providing commentary on broader philosophical and social issues that will shape and configure our futures. There appears to be a limitation in these studies, namely, a lack of consideration of the bigger picture. This is the gap that this dissertation aims to address in the field of SRF.

Yang et al. concede that SRFs 'functions are limited due to dedicated design', so this dissertation looks into why and the types of challenges the field faces in bringing a functionally and aesthetically desirable SRF that can be readily adopted. I will begin the process of considering SRFs by taking a brief step back to examine the evolutionary progression of the human hand from an anthropological

[13] Bo Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," *IEEE transactions on medical robotics and bionics* 3, no. 3 (2021): p623, https://doi.org/10.1109/TMRB.2021.3086016.
[14] Yuchuang Tong and Jinguo Liu, "Review of Research and Development of Supernumerary Robotic Limbs," *IEEE/CAA journal of automatica sinica* 8, no. 5 (2021): p929, https://doi.org/10.1109/JAS.2021.1003961.

and evolutionary perspective, considering the impact of its design and morphology on technology. The examination of SRFs begins with an investigation into how the human ability to provide different grasps, facilitated by our capacity for an opposing thumb, has enabled the flourishing of art, culture, and writing, as well as its broader impact on civilisation and technology (Appendix 2). This is done to put into perspective the importance of the hand, especially the thumb, which sets the scene for the examination and the implication of a third-thumb.

There are numerous technical and moving parts to the SRF. The dissertation will attempt to convey these concepts in a manner that keeps the technical aspects as simple as possible, without becoming overly complex in mechatronics or physics. It will also attempt to briefly relate to the wide range of related fields of research to which SRFs can lend themselves, such as embodiment, agency, neuroscientific, and cognitive studies, which are largely outside the scope. In the research into SRFs, the dissertation examines multiple dimensions: underlying theoretical frameworks, implicit biases, organisational structures, designer intentions, user engagement, researcher positionality, approaches to technological challenges, patterns of scientific collaboration, sources of inspiration, and how these elements collectively enhance our understanding of subjectivity and the user experience. The insights are assembled through these lines of investigation. The SRF exploration section of the dissertation shall methodically examine the various dimensions of the designs, including the technologies used to drive the SRFs, the methods of control, the systems that provide sensing and feedback to the body, and their design ontologies, derivations, and deviations. This is done to give the reader a sense of the discourse and the issues that are part of human-robotic interaction and augmentation of the body. Yang et al.'s comments that SRF's 'functions are limited due to dedicated design'[15] indicate the many challenges facing the production of a true third-thumb. These views, provided by the researchers, enable further examination and critique of the issues surrounding the organisation of the field and the conception and development of design ontologies, including their subjective political and social awareness and their effects. Prattichizzio et al. sum up insightfully:

> SRLs can be used to compensate for lost functions in patients with motor deficits and, more in general, to augment the sensorimotor capabilities of humans to interact with the environment. The design and control of SRLs present several challenges. SRLs must have high levels of ergonomics and wearability and, depending on the application, they might also require enhanced robustness and strength. Supernumerary robotics differs from collaborative robotics, since SRLs are not collaborative

[15] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook."

> external agents but rather act under the direct command of the operator who, thanks to the use of suitable interfaces, gains the control of some actions of the SRLs.[16]

Given Prattichizzio's insights into the issue that makes SRF so distinct from collaborative robotics and its intimate relation with the body, combined with the technical complexity, the dissertation will focus on this relationship, and by engaging Guattarian subjectivity, consider how subjectivity can create reflective research practices and bring about innovation that breaks free from the domination of set ideas, practices and habits to find solutions to material challenges. The idea would be that if subjectivity were free to follow its traces of desire, it would engender productive change in the practice of research, its stewardship, and the outcomes that would benefit individuals through a convivial scientific and design process. I focus on particular sets of SRF projects and employ Guattarian psychoanalytical practices to critique and provide insight into the dynamics underlying the processes and design ontologies of various projects. I will aim to process the analysis of various projects, focusing on their successes and failures, as Guattarian subjectivity permits me to do so by placing the field of SRF on the psychoanalyst's couch (or in group therapy), as if it were a patient. I provide commentary guided by theory to critically relate the discourse on design practices in the field of SRF to the paradigm of a third-thumb. By extension, I also tie together the designs of SRF made from the body with the design of architecture that shelters the body, taking its cues from the body to include a reassessment of the role of architecture in the production of subjectivity. In this reconsideration, I shall also propose reevaluating architecture as a more dynamic, epistemological, temporal and ontological practice that produces subjectivity and directly influences its environment. By extending these ideas of SRF subjectivity through my proposition of *techno-subjectivities*, it is hoped that there will be an increased understanding of how Guattarian ideas of subjectivity and technology can shed light on their practical applications, bringing about flourishing autonomous individuals who are in charge of their own destinies while relating to deeply connected and rooted ethical social networks.

At this point I have to also mention that throughout this dissertation, I distinguish between *technics* and *technology*, though some slippage between the two is unavoidable. *Technics* refers to the broader regime or logic that organises technical operations—the mode through which knowledge, action, and perception are structured. *Technology* refers to specific objects: particular devices, systems, or artefacts. For example, computational technics operates through logics of data extraction, prediction, and optimisation; specific technologies—recommendation algorithms, fitness

[16] Domenico Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," *Progress in biomedical engineering (Bristol)* 3, no. 4 (2021): p1, https://doi.org/10.1088/2516-1091/ac2294.

trackers, platforms—instantiate this technical regime in concrete forms. This distinction matters for understanding techno-subjectivity: subjectivity is produced not simply through individual technological objects but through the technical regime itself. Different technologies can embody the same underlying technics, meaning that replacing one app or platform with another may leave the mode of subjectivation fundamentally unchanged. When analysing how technical assemblages produce subjectivity, we must attend to both the specific technologies encountered and the deeper technical logics that constitute the regime. Where I use 'technology' to discuss regime-level operations, this reflects the material entanglement of technics and technology in actual assemblages.

Objectives

Given that this dissertation aims to explore the intersections between Rolnik and Guattari's psychoanalytical theories of subjectivity and the field of SRF research, the objectives of this dissertation unfold in a sequence that allows each objective to contribute to the aim. The flow of logic (from objective to objective) is reflected in the chapter structure. Five objectives guide this inquiry: (1) Review Guattari and Rolnik's ontology of subjectivity; (2) Conduct a comprehensive survey of SRF research and design paradigms; (3) Integrate theoretical frameworks with the discourse on technics of the third-thumb; (4) Explore socio-political implications of SRF augmentation through concepts like transversality; and (5) Speculate on architectural transformations prompted by techno-subjectivities. These objectives collectively aim to demonstrate how prosthetic technics can catalyse emancipatory practices and reconfigure social environments.

Objective 1: To explore the subjectivity that unfolds via Rolnik and Guattari's book, *Molecular Revolution in Brazil*

The first objective is to review Rolnik and Guattari's ontology of subjectivity, with close attention to their book *Molecular Revolution in Brazil* (2008). 'The process of subjectivation'[17] , which produces the subject, is dependent on Rolnik and Guattari's ideas that capture the coming together of a diverse set of concepts using a complex set of terminologies that need to be explicated to help define the discourse on the production of the individual, its psychoanalytical life, and the influences the structures that support its development relates and contrasts with the traditional understanding

[17] Guattari, *Molecular Revolution in Brazil*, 1, p43.

of the individual and its collective relationships. I shall not look at any other theorist or ideas other than those that I can trace an influence upon Guattari directly. Although I shall briefly explain where Guattari gets some of his ideas, such as his Marxist ideas, his psychoanalytic critique of Sigmund Freud and Jacques Lacan, and his interpretation of semiotics via Louis Hjelmslev, amongst the broad field of reference to ethological, ecological, sociological, and anthropological theorists, I shall concentrate on the outcome of his own derivations for subjectivity. In this regard, I tread gently with the work that Guattari conducted with the philosopher Gilles Deleuze and tend to concentrate only on Guattari's identifiably singular work. This is because I wish to elaborate on the psychoanalyst's deep understanding gained from a lifetime of work peering into subjectivity through his political activism and his experience treating the mentally ill. The book *Molecular Revolution in Brazil* was written by two psychoanalysts, Rolnik and Guattari, and I tend to focus on the Guattarian ideas and therapeutic practices.

Guattari has gained a unique insight into the complexities of the social constructs and structures that create such environments, represented in the manifest mental and sociological mental health issues that are a product of the intersection of the individual unconscious and its struggles to make sense of an often very conflicting set of ethical, political, economic, as well as institutional and environmental circumstances. We can consider that there are no distinct social, economic or political divisions in Guattari's work. They are all intertwined and part of the same environment. I shall evaluate and explore the complex set of thematics (a chosen set of thematics and submathematics that shall be named and outlined in detail later) that forward Rolnik and Guattari's perspectives on subjectivity and how they can help transform their environments and situations in revolutionary ways. I will outline key ideas and their significance, and explain how they relate and elaborate on each other. This objective is thus an attempt to unravel the various systems and ideas on which Guattari builds his concepts, including how subjectivity is implicated in the pull and push of capital, the politics of dominant systems and hierarchies, and his critique of the *psy* sciences.

The dissertation will contextualise the use of the examples in the book to consider subjectivities as they relate to groups such as minorities and the marginalised, patricularly through Guattari's understanding of the *collective unconscious* and the psyche. This will explain how Guattari's subjectivities and collective voices mobilise their inner force for life to free them from the shackles of blame and shame, as well as their enslavement to the hegemonic politics of assemblages that include semiotics, often operative in social coding and structures. In so doing, I shall try to understand how Guattarian subjectivity offers a voice to the dispossessed and disenfranchised as a way to benefit all.

Objective 2: Develop a thorough understanding of the field of Supernumerary Robotic Fingers (SRF)

The second objective of this dissertation is to conduct a thorough review of the current literature on SRF, also referred to in this dissertation as the paradigm of a third-thumb. Although not all SRFs may necessarily be a true third-thumb, this term is used to encapsulate the idea of an augmented SRF. The dissertation will evaluate the research papers on SRF, attempting to interpret the innovations, some for their design morphologies and others for their complex technologies. This exploration seeks to relate the more interesting features of the SRF, such as how the SRF operates, the ideas and innovations behind the research inventions, in what ways researchers view the context of their work, what resounding thoughts they have for their research, their applications and their view of the user, the biases researchers display and to build on these investigations ultimately. Other ideas to be explored include the consideration, or lack thereof, by research groups or individual researchers of the scientific epistemology on which they build their ideas and their relationships to other research projects through the transfer of epistemology. The dissertation will also attempt to understand the issues and challenges of augmentation, ease of use, and future applications, but only from the perspective of the scope of SRF design, rather than issues of embodiment, despite a brief discussion of embodiment. This is because embodiment and its phenomenology of the hand, although in its nascent stage, is too expansive a field and will not necessarily shed light on the objectives and aims of this dissertation. What is also beyond the scope of this dissertation is the examination of the various complex computational, mathematical, and engineering-based mechatronic concepts in the research to either validate or dispute the basis of the physics, electronics, robotics, or other technical aspects of these research papers, as well as the computational intricacies of various experiments. Detailed computational analysis contributes little because the same principles that drive this type of analysis are evident in the core principles of designs undergirding particular research innovations when viewed through the lens of subjectivity. I shall seek to uncover the designs and core ideas behind the technology and its research, and identify the variation and particularities of each design, as well as its discourse and its relation to the user. This dissertation will not include any other type of supernumerary limb, arm, or leg.

I shall review the latest projects individually, which have come to represent the discourse in the field of SRF, characterised by a particular type of discourse over the past decade and a half. The field of SRF is a very small, burgeoning field with innovators and conventionalists. Researchers who have developed SRF projects tend to come mostly from fields such as robotics, engineering, mechatronics, biomechanics, and other related fields, whose perspectives are often highly technical. Consequently,

they tend to view SRFs and their various design outcomes through a technical lens rather than through the lens of philosophy or psychoanalysis. The dissertation will explore their work and examine the various project associations and collaborations, providing a comparative and critical review of them throughout the various stages of my research and the connections made.

Objective 3: Bring together two disparate fields of Rolink and Guattari's subjectivity and the field of SRF

The third objective of this dissertation is to engage with Rolnik and Guattari's framework of subjectivity, exploring how these conceptual ideas manifest through the augmentation of an SRF. I shall propose how these ideas transform the notion of SRFs into a paradigmatic proposition of a third-thumb augmentation and how the position of Guattarian subjectivity resonates with SRF discourse. I will demonstrate how Guattari's ideas can transform our habitual view of a prosthesis (beyond its use by people with disabilities) by integrating these ideas. This transformation can also alter our view of its object-subject relations into a rethink via Guattari's *machinic assemblage* of object-subject intersections that opens the body as a revolutionary social and political site of activism and one that engenders an unconscious collaborative production of desire through the use of an SRF as prime mover to build networked individuals with stronger social bonds. These ideas will foster consideration of how Rolnik and Guattari's theory of subjectivity may help reorient and address changes to our current social schisms and future challenges as we approach issues right before us. The idea here brings into focus the social, technological, and political environmental alterations that necessitate a change in the ecology of subjectivity and its impact on the field of SRF, aiming to create free, autonomous individuals in line with the interests and values of free and connected ethical collectives.

Driven by a small set of core ideas (concepts) that underpin Guattarian subjectivity, the dissertation first explores the implications of each concept separately in relation to a particular feature of SRF. For example, in Chapter 4B, I first discuss what is meant by Guattarian *machinic transversal assemblages*, as well as the concept of *machinic assemblages*. Then, I examine the various technical mechanical components that comprise the SRF, along with examples that demonstrate how the two concepts of mechanical and machinic systems work in the field of SRF, both as individual components and as assemblages. Following these separate explications, by intersecting the latter and former, I explore Guattari's idea of *machinic assemblage* and how it gives rise to various ways of understanding and viewing the augmentation of SRFs and their operation in society. I discuss and propose ideas aimed at challenging how SRFs can transform our understanding of the subject-object

relationship and the social, political, and economic repertoire, which can significantly alter our notions of subjectivity and our roles within society. The dissertation will explore this concept through various conceptual themes that define and underlie numerous ideas proposed by Guattari, while examining the dimensions and challenges facing the development of a usable, ubiquitous third-thumb for human augmentation.

Objective 4: To explore the socio-political implications of SRF technics through Guattari's theoretical lens (techno-subjectivity)

My fourth objective is to examine the broader social and political implications of SRF technology through the lens of Guattari's theory. I shall investigate how the third-thumb paradigm elicits what I term *techno-subjectivity*, exploring how these technics of the third-thumb might reshape social dynamics through local and individual advancement, tracing paths of subjective development through provocations and psychoanalytical processes. This involves informed speculation on the concept of *techno-subjectivity*.[18] This type of subjectivity, derived from Guattari, fosters consideration of the role of technologies in the transformative turn of individuals. Such a 'turn' might be in relation to social connectivity via orality, illocutionary, locutionary and communicative utterances, or what Guattari refers to as *assemblages of enunciation.*[19] The machines of Guattarian ideals are not just technological but also inculcated in his machinic ideals of social systems, economic, 'iconic, ecological, ethological, or media systems, in other words, systems that are no longer immediately anthropological' but which provide the grounding for 'machines of expression'.[20] Techno-subjectivities and their collective *machinic assemblages* of enunciation open various relations to free societies, transformative sciences, and other equitable economic, non-hierarchical social, and political ecologies, potentially creating a more diverse, open, *autonomous* and *smooth* society through *molecular revolutions*.

Objective 5: Prompting future thought on how techno-subjectivity implicates architecture

This dissertation's fifth and final objective explores the trans-augmentation of the SRF that precedes techno-subjectivities. This objective also serves as a conclusion to the research, providing a speculative reconsideration of architecture. The validation of the body and its extensive situatedness

[18] Techno-subjectvities is a term coined by me that comes close to what I believe is equivalent to Guattari's 'Informatic subjectivity'. This term is not fully illucidated but is part of winder discussion in his chapter '5 Machinic Orality and Virtual ecology' in his book, Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p96.
[19] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p97.
[20] Guattari, *Molecular Revolution in Brazil*, 1, p43.

within its environment opens the possibility for transforming the individual's intrinsic apparatus, creating new connections and networks of social alliances and expressions through a body-oriented architecture that operates precisely at the boundaries of peripersonal space. This will be framed as a relationship to objects that transforms them into a dynamic force of subjectivity. I interconnect the idea of SRF design and its ontological nature as one that enfolds a new architectural proposition. I shall argue that the connection between the body, the SRF, and architecture forms a single, binding assemblage, which is how techno-subjectivities can be considered. This requires us to reconsider architecture not just as a design practice of the technics of augmentation and bodies, bricks and mortar, but rather as an extension of subjective desires from its virtual a priori in the unconscious to its design manifestation, and then its ongoing recurrences in memory and intensities (as with my own childhood home). There is a capacity here for extending the body through architectural design and psychophysical practices that might foster a new type of dynamic relationship with its surroundings. This is not merely reconsidering how we think about space, but also how we consider the body in social spaces and its micropolitical dimension in a system of direct interconnection between the object and the subject. The new architecture is redefined and inspired by Guattari's *machinic* and *ethico-aesthetics*. The body herein might be thought of not just as a site for the inanimate architectural forms but rather a live architecture of subjective expression.

Methodology

Iain Borden and Katerina Rüedi's explanation of the unique nature of the current discourse in architecture elucidates the type of critical methodology employed in this dissertation. In their book *The Dissertation: A Guide for Architecture Students* (2014)[21] , they suggest 'critics today often make increasing reference to theories and disciplines from outside architecture.'[22] They include in this interdisciplinary field architects looking to areas such as 'semiology,[…] post-structuralism and literary theory, […and] psychoanalysis'.[23] They go on to suggest, '[t]his is a growing area in architectural research which has emerged as architectural writers have begun to look to other disciplines to find interpretative frameworks, research methods, primary sources and secondary literature in order to explain architectural issues'.[24] As such, this dissertation's logic is very clear, adopting an interdisciplinary method described by Bordern and Rüedi to understand how the body

[21] Iain Borden and Katerina Rüedi Ray, *The Dissertation: A Guide for Architecture Students*, Third edition. ed. (Oxford: Routledge, 2014).
[22] Borden and Ray, *The Dissertation: A Guide for Architecture Students*, p24.
[23] Borden and Ray, *The Dissertation: A Guide for Architecture Students*, p24.
[24] Borden and Ray, *The Dissertation: A Guide for Architecture Students*, p24.

might be a site both for theoretical explication of Guattarian subjectivity and how that extends our understanding of augmentation with an SRF or a third-thumb (techno-subjectivities), and (by way of conclusion) what that means for architecture.

In any interdisciplinary endeavour, one must be highly mindful of the disciplinary forces and practices involved. The exploration of the roles and capacities of the third-thumb is grounded in the methodologies of architectural theory and Science, Technology, and Society (STS) studies. The research will also draw on methodologies from the work of philosophers of science, such as Isabelle Stengers[25] and Bruno Latour[26], who strongly advocate for an object-oriented understanding of research practices as an artefact that interjects into how people are affected. Latour suggests in a chapter called 'Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts' in the book edited by Bijker and Law, *Shaping Technology/Building Society: Studies in Sociotechnical Change* (1992) that:

> [t]hose advocating the actor network approach agree with the social constructivist claim that sociotechnical systems are developed through negotiations between people, institutions, and organisations. But they make the additional interesting argument that artifacts are part of these negotiations as well.[27]

This dissertation also draws on a particular Guattarian concept used here as a method. Simply, I am using the theory to map the cartography of relationships as a method, namely the concept of schizoanalysis. As a method, schizoanalysis deconstructs dominant narratives of SRF technics and subjectivity by mapping assemblages of humans, artifacts, and desires. And how this occurs is revealed in the structure of this dissertation, which is found in the relationships among the discourse, the theory, the third-thumb, and the case studies that map the desires of its inventor and users. Thus, in this dissertation, the SRF artifact and its third-thumb paradigm serve as a method for understanding people, society, politics, and various dynamics, including what have traditionally been thought of as object-oriented fields such as architecture. The artefact itself comes to be framed as an object that is both in construction and constructs. Whilst the considerations of the SRF and the paradigm of a third-thumb are grounded in STS, the exploration of the ideas of Rolnik and Guattari is grounded in humanities-based theoretical investigation. That is, this dissertation endeavours to thoroughly consider the core text, *Molecular Revolution in Brazil,* as an exploration of its antecedents and the implications that flow from the text, including secondary sources and

[25] Isabelle Stengers, *Cosmopolitics*, Posthumanities ; 9-10, (Minneapolis, Minn. ;: University of Minnesota Press, 2010).
[26] Bruno Latour and Peter Weibel, "Making things public: Atmospheres of democracy," (2005).
[27] Wiebe E. Bijker and John Law, *Shaping technology/building society: studies in sociotechnical change*, Inside technology, (Cambridge, Mass: MIT Press, 1992), p151.

commentary, to examine the key notions from the text, particularly those related to subjectivity itself.

The coming together of the two—of the artefact and the theorisation—will take the form of a humanities-based critical exploration, albeit one with a clear eye upon the artefactual nature of outcomes.

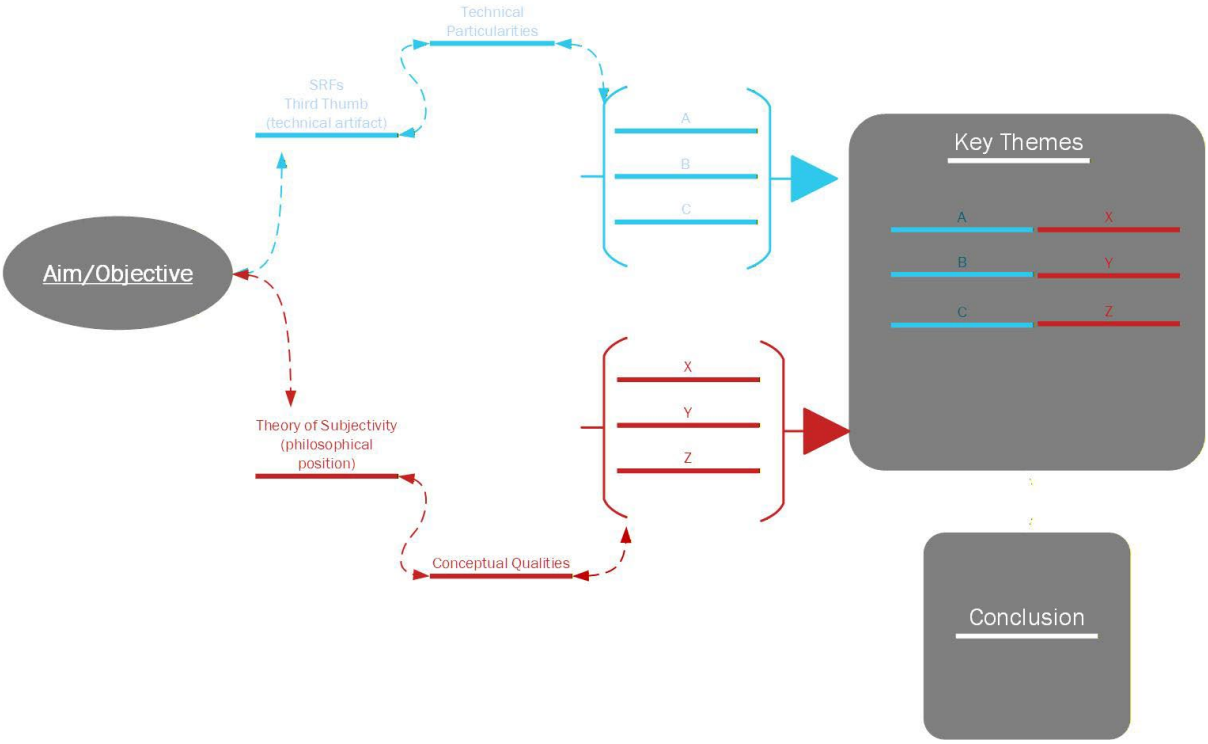

Figure 1 - Methodology of the dissertation visualised

Thus, the method developed here combines two distinct but interconnected streams, as shown in Figure 1. The first stream is the technical particularities – examining SRF technological artefacts, their design paradigms, and the technical challenges, as denoted by A, B, and C, and so on. The second stream is the conceptual qualities – unpacking Guattari and Rolnik's psychoanalytic theories of subjectivity as denoted by X, Y, and Z, focusing on concepts such as transversality and *machinic assemblages*. The diagram in Figure 1 illustrates how these streams remain separate yet converge through comparison, allowing key themes to emerge organically. This approach does not pre-empt a conclusion. Like Guattari's theories, it is a method for experimentation, enabling ideas to surface without being presupposed or predetermined.

The research process was deliberately open-ended: technical and conceptual dimensions were kept distinct, and their integration was guided by the intensities that emerged from the work itself. Rather than forcing alignment, the methodology allowed unexpected connections to form, A-X, B-Y,

C-Z, as an example, producing insights that reflect the dynamic interplay between technics and subjectivity in an attempt to provide rigour.

Thus, in this thesis, the streams remain distinct to preserve the integrity of each domain before allowing them to meld and interact through emergent comparison in Chapter 4 series, where key themes reveal the characteristics of schizoanalysis and the discourse on techno-subjectivity.

Structure by chapter

Chapter 1 – Introduction

Chapter 1 provides an overview of what inspired this investigation, how it will unfold, and what is examined through this route. The chapter sets out the background with a personal explanation of how I came to view the world through architecture, and why it is such a strong object of relation in my (personal) psychoanalytic life.

The aim of this dissertation is introduced: the exploration of the intersections between Rolnik and Guattari's psychoanalytical theories of subjectivity and the field of SRF research, with particular attention to the augmentation of a third-thumb. The objectives unfold this aim and involve a review of Rolnik and Guattari's understanding of subjectivity, then turning to the field of SRF to trace its core logics and artefacts, then exploring SRF as an analyst might trying to unravel the complex set of associations between subjectivity, its unconscious and its social relations, and in so doing offer and refreshed understanding of the body-architecture relationship. I outline the objectives that guide my approach, walking through the five objectives set to achieve the dissertation's main aim.

Through an interdisciplinary framework and methodology that utilises an interdisciplinary approach, combining STS and the humanities to examine the interrelation between objective and subjective phenomena, I analyse the philosophy of Rolnik and Guattari to explore the relationship between the body and the SRF. I conclude this chapter with a list of key definitions (in Appendix 1), which also helps establish the scope of the dissertation and the key terms of reference.

Chapter 2 – Rolnik and Guattarian ideas on subjectivity

This chapter provides an exploration of the concepts introduced by Rolnik and Guattari, as outlined in their book, *Molecular Revolution in Brazil*.[28] The book, *Molecular Revolution in Brazil*, is an exemplary assemblage of a range of Brazilian subjectivities through various voices of an ethnically diverse country. This book captures a snapshot of the early 1980s, when Brazil experienced significant social, political, and economic turmoil. A moment of inflection and change. In the foreword to the book, Guattari writes;

> Before being a work on philosophy, sychoanalysis or politics, this book is a kind of travel journal. Suely wrote it after the trip that she and I made across Brazil, looking for individuals and groups as well as being found by intensities and desires along the way. These fragments, blocks of ideas, pieces of conversations, letters, debates, conferences, confidences—montages that Suely has made of statements by me, by her, by many others—are then a break with the bonds of the individualization of enunciation. They are, I would say, a love at first sight with the collective intelligence and sensibility of this country.[29]

This chapter explores key themes that the two psychoanalysts use to define subjectivity and offers an interpretation of the text, referencing the life's work and thoughts of Guattari. This definition of subjectivity is radically different and a departure from what we are used to. As such, the themes I have selected to explore their definition have been curated to examine some key ideas about how their processual exploration of subjectivity operates in a socio-political and economic environment. The themes of subjectivity encompass the exploration of concepts such as *schizoanalysis*, *the machinic*, *group therapy*, *transversality*, *revolution and creativity*, as well as the concept of *new smoothness*. Attached to these are also several subthematics, such as the meaning of *identity, individuation (or serialised subjectivity), minorities and autonomy, desire,* the *unconscious,* the *process of singularization,* the discourse of *semiotics* and its impact on the unconscious, the *rhizome, micropolitics (micro and molar), Marxism,* and resistance.

By the conclusion of Rolnik and Guattari's exploration of subjectivity, the idea of transversality emerges as the underpinning process for all the other themes and subthemes, which then translates into the structures of future chapters and an overarching approach to exploring subjectivity. Rolnik and Guattari explicate the concept of subjectivity in contrast to how modern capitalistic societies of

[28] I also refer to a very interesting lecture by Rolnik, which later formed the basis for her book translated into English in 2023 called *Sphere of Insurrection: Notes on Decolonizing the Unconscious*. Suely Rolnik, *Spheres of Inscurrection: notes on decolonizing the unconscious* (Cambridge, UK: Polity Press, 2023).
[29] Guattari, *Molecular Revolution in Brazil*, 1, p3.

today (which they refer to as *Integrated World Capitalism (IWC)*[30]) produce subjectivity. This is achieved by critiquing Marx, Freud, and Lacan as primary targets, among many other structuralist thinkers. Rolnik and Guattari extend these thoughts to the deployment of subjectivity and critiquing culture, institutions, and political parties. They trace the tension between identity and subjectivity, sex and sexuality, and the alienation of the individual and describe the captive state of the collective. Then, Rolnik and Guattari explain how the power dynamics that enslave subjectivity affect the status of minorities and minoritarians, as well as the mentally ill and their impacts on broader society, through their discussion of relations with concepts such as *micropolitics*, which are closely associated with Guattarian ideals of the *molar* and *molecular.* Through their reformation of group dynamics, via their alternative reading of psychoanalysis and subjectivity, they offer an alternative way in which territories of desire can provide new insights into the historical past and our futures. Through their reinterpreted notion of subjectivity, we can begin to understand the individual as something that might be liberated and given autonomy by breaking away from the domination of coercive forces, including capital, the church, the political party, the state, the media, mass culture, and other controlling forces. Rolnik and Guattari's conception of subjectivity is framed as one set free from the grid of control, allowing individuals to follow their creative paths of self-styled identification through the 'processes of singularization'[31] that produce free individuals via unrestricted destinies becoming productive members of collectives while encouraging ethical cooperation. The spelling of the term singularization shall be kept with 'z' from here on in to emphasise the unique use of the term throughout this dissertation.

Chapter 3 - The field of Supernumerary Robotic Fingers (SRF) and its many manifestations

This chapter provides a review of the SRF, from its nominal inception to the present. The most prominent work dates from 2015 to 2024. Although this study spans nine years, the research dates back fifteen years.

The chapter explores various types of SRF inventions and their applications as prosthetics and augmentative devices to supplement the fingers of the hands or as part of other technical or

[30] In *Molecular Revolution in Brazil*, Félix Guattari defines Integrated World Capitalism (IWC) as a global system of economic, social, and political domination that integrates and subsumes various forms of production, consumption, and desire. It goes beyond traditional capitalism by extending its reach into all aspects of life, including culture, subjectivity, and individual desires. IWC operates through the control of media, technology, and other societal structures to produce and regulate subjectivities in ways that align with capitalist objectives, homogenizing social relations and eroding traditional forms of resistance. The system is "integrated" because it merges both material and immaterial production, making subjectivity itself a key site of capitalist reproduction. Guattari, *Molecular Revolution in Brazil*, 1, p10,p27.

[31] Guattari, *Molecular Revolution in Brazil*, 1, p23.

cognitive experiments related to augmentation. Some papers reviewed will utilise SRF inventions to assess neurocognitive or behavioural reactions, while others will test mechatronic mechanisms (such as motors and sensors). Whether the SRF is a collateral invention or the primary object of their project, the production of SRF artefacts shall become the focus of this review, as will anything related to the user or questions of subjectivity. The review will extract SRFs from other types of SRL to focus on the hand only, and may include more than a single extra finger (or thumb), all the way up to prosthetic hands and gripper devices. The term SRF will refer to the broad term that encompasses and includes any device resembling a third-thumb. The Third Thumb (as distinguished by its typography) is also referred to as a particular proprietary device named by one particular project to identify their invention, which shall be the later focus of this dissertation. However, the term 'third-thumb' or 'the paradigm of the third-thumb' will frequently emphasise its broader connective issues to subjectivity. Other proprietary terms are used, such as Sixth Finger, Robotic Gripper, Controllable Third Thumb, SR3T (Supernumerary Robotic 3rd Thumb), Wearable Robotic Extra Finger, Novel Monolithic Soft Robotic Thumb, and so on. I shall use the term' paradigm of the third-thumb' or 'the third-thumb' when referring to broader issues relating to technics of the third-thumb to subjectivity and its connections to various social, economic, and political aspects. I shall refer to 'SRF' or 'the field of SRF' when referring to the artefact in its objective state as a piece of technology divorced from its extensions but immersed in the scientific context.

Over thirty SRF projects shall be reviewed for their inventiveness (or lack thereof), and the variety of ideas these projects present by reading between the lines of scientific thought. These ideas will be utilised in future chapters in more detail to discuss their comparative roles in evaluating the critical theoretical impact on subjectivity when integrating Guattarian subjectivity and SRF into a multifaceted discourse.

Chapter 4A Series prologue - Encapsulates five chapters from 4A to 4E, bringing together disparate domains of transversality of subjectivity and the field of SRF

The following five chapters form a series of 'Chapter 4'—from '4A' to '4E' — all relate to one key theme that brings together all other themes to do with the idea of Rolnik and Guattarian subjectivity, called *transversality*, and its various conceptual qualities, as well as the subthemes that underpin the idea. *Transversality* is the central conceptual engine of this thesis. It breaks hierarchical structures and opens diagonal, non-linear connections across domains. *Transversality* refers to the capacity to create connections and interactions across different layers of the virtual and the real, including the psychic, social, political, and material dimensions. It challenges hierarchical structures

(both in institutions and in thinking) by promoting a non-hierarchical flow of relations between different components of subjectivity, institutions, and environments. Transversality enables the formation of new assemblages of desire, subjectivity, and social relations by disrupting fixed systems of thought, such as those found in psychoanalysis, politics, and capitalism. Transversality collects, and is related to, many key ideas from Guattari's life's work and covers key texts such as *Psychoanalysis and Transversality: Texts and Interviews 1955-1971* (2015), originally published in French in 1972, *Molecular Revolution: Psychiatry and Politics* (1984), first published in French in 1977, *The Machinic Unconscious: Essays in Schizoanalysis* (2011), originally published in French in 1979, together with the primary text of this dissertation *Molecular Revolution in Brazil* (2008), first published in Portuguese in 1986.

In summary, transversality is multifaceted: it is a function of the expansion of psychoanalysis and the cornerstone of schizoanalysis. Transversality walks a fine critical line between institutional psychotherapy and transference. Transversality opens the delimitation of transference, diversifying the outlook of its semiotics. It is a means of diversification of semiotics at all levels of analysis, not just of Freudian and Lacanian myths and mathemes. It extends transference and interpretation. It deciphers all modes of semiotics and expression, drawing on a wide variety of references that encompass understanding desire, politics, society, economy, and the environments to which we are bound. Transversality breaks free from the walls of silence in systems of therapeutics and transference. Transversality is a metabolism of inputs and outputs. It is creativity. Transversality is characterised by communication, dialogue, and messaging that is rich in content and information. Transversality is rhizomic and polyvalent, subverting privilege. Transversality opposes the vertical and horizontal. Transversality has different meanings; it escapes hierarchy and is revolutionary. Transversality operates subjectivity, and its mechanisms reflect and analyse flourishing societies. Transversality liberates the individual from capital and the industrial complex, opening up subjectivity to freedom and collective interests. It operates between groups to emancipate them into their own laws and desires. It lifts the minorities and the marginalised. Transversality forms new alliances and breaks from the habitual. Transversality is the transition away from anxiety and neurosis. It always aspires to heterogeneity. Transversality is unconscious, manifests at the molecular level, and self-reconfigures in waves and ripples, connecting classes and social strata. Transversality carries a new smoothness to society. It has power, inertia, and a coefficient of openness and anticipation. Transversality can serve as a mirror to subjectivity, helping one become singular, open, and unique. It's a process, a thing, and it's powerful. It is meaningless and full of meaning.

There is a deep relationship between the meaning of transversality and its operative subthematics when brought into connection with the sphere of analysis of the field of SRF that the Chapter 4 series wishes to explore. By examining the subthemes of transversality and the particular issues in the field of SRF individually, and then integrating the two disparate fields, I explore how subjectivity and technology (and hence the technics of the third-thumb) interact in this series of chapters on transversality. Key subthemes include *schizoanalysis*, which maps desire as a productive force rather than a pathology; transference, which Guattari critiques for its insularity and is replaced by transversal flows that connect individuals to collective creativity; and *the rhizome*, which resists arborescent hierarchies and fosters multiplicity; the idea of *singularization*, which enables individuals and groups to break free from capitalist modelisation and form self-styled identities through creativity and desire. Next is the developed idea of the concept of *coefficients of transversality*, which measure openness and responsiveness in systems and groups, enabling innovation and ethical transformation. These ideas underpin the move toward *minoritarian subjectivity*, freeing individuals from capitalist subjectivity and enabling singularization. And finally, the subtheme of *machinic assemblages*—a dynamic network of human, technological, and semiotic components—becomes the operative site for producing new forms of subjectivity.

Chapter 4A - Transversality: breaking away from the traditional forms of analysis

Chapter 4A serves as a starting point for introducing the Guattarian concept of transversality, which underpins the notion of subjectivity in relation to an SRF's, polydactyly and the concept of minorities in general. Understanding the importance of transversality in relation to augmentation and desire is both evolutionary and revolutionary. The dissertation will argue that the concept serves as an entry point to Rolnik and Guattari's broader ideas on the social and psychoanalytical transformation of subjectivity. This understanding will be developed via three key concepts (subthemes): *schizoanalysis*, *transference* and the *rhizome*.

Schizoanalysis is a methodology that breaks down rigid structures in both psyche and social institutions, promoting fluid connections across psychic, social, and political domains. It maps desire as a productive force operating within assemblages of bodies, signs, institutions, and machines, rather than being fixed to familial structures, as in traditional psychoanalysis. When combined with semiotics, it becomes a way to understand how signs and meanings are produced within broader assemblages of desire, power, and the unconscious, moving away from fixed meanings toward more dynamic, heterogeneous modes that shape subjectivities and social relations.

Guattari develops transversality through his critique of *transference*. Transference involves projecting childhood relationship patterns with caregivers onto other relationships later in life. While traditional psychoanalysis focuses on these Oedipal projections in a closed loop, transversality breaks open these personal processes to broader social and political fields. It creates fluid, non-hierarchical connections across multiple domains, enabling new subjectivities and collective expressions. Where transference stays within familial references, transversality pushes beyond these limits toward collective, revolutionary engagement with the material world.

Transversality works *rhizomatically* – concerning decentered, self-rooting connections that link various dimensions in heterogeneous ways. Like a rhizome, it spreads without central points or hierarchies, crossing structured boundaries to develop unexpected alliances and establish horizontal networks of connections.

At this point in the chapter, I turn my focus exclusively on the issues related to SRFs. I will reserve the explanation of transversality for later in my critical analysis, which will bring together SRF and the conceptual and theoretical ideas of transversality. When discussing SRFs, I focus on the discourse in papers that discuss ideas related to the subject, such as the discourse on polydactyly and the subjectivity of augmentation, considering the different characteristics of augmentation. I follow the discussion of researchers and their views on either substituting a finger or supplementing a finger to decipher their perspectives and understand the key points of difference in the discourse.

Combining the key ideas (conceptual qualities of transversality), schizoanalysis, transference, and the rhizome with respect to the paradigm of third-thumb and evaluating the issues at hand with regards to SRF, I progress into an analysis and critical evaluation of how issues of subjectivity discussed by Guattari offer insights into the discussion of SRF, challenging the field of research.

Chapter 4B - The machinic unconscious of SRFs

In Chapter 4B, I draw together Guattari and Rolnik's concept of the *machinic*, which grounds transversality and the contentious analysis of SRF systems as purely mechanical objects. The chapter does so in order to argue that machinic systems comprise the transversal ruptures and semiotic functions of a trans-augmentive subjectivity. I will define the machinic nature of transversal assemblages through the concept of the *machinic unconscious*. The term 'machinic' in Guattari's work refers to systems or assemblages that are not mechanical in the traditional sense but rather describe how various components (human, non-human, technological, biological, semiotic, and social) interact to produce effects, flows, and transformations. A machinic assemblage is a dynamic,

processual network that involves multiple entities working together to generate new realities or subjectivities. Machinic assemblages function across different fields—social, psychic, technological, and political—operating through a non-hierarchical, open-ended interaction. They are not confined to rigid structures or binaries (such as subject/object or human/machine), but instead facilitate the flow of desire, meaning, and material forces. Machinic processes are deterritorialising, meaning they break away from fixed categories or territories and form new connections, allowing for the continuous transformation of subjectivities and systems.

I then turn my attention to the field of SRF, where I examine the various mechanical and machinic systems in the discourse on SRF and make some important distinctions from which I shall later draw some perspectives on how Guattarian machines and mechanical systems operate subjectivity. By making these intensive connections, I expand on the various challenges in the field of SRF and draw on extensive ideas that intertwine Guattari's machinic ruptures with the prevailing innovative ideas evident in the discourse.

In this chapter, the transversal ruptures and semiotic functions of the trans-augmentive subjectivity of the SRF are explored.

Chapter 4C - Transversality and transmission in SRFs via group therapeutics

In Chapter 4C, I examine how Guattari's concepts of transversality and group therapeutics intersect with the field of SRF, investigating both the physical transmission systems in human-robot interactions and the psychological dynamics of research groups. Ultimately, I propose a revolutionary approach to scientific innovation through Guattarian frameworks of subjectivity. I explore how transversality and *group therapeutics* (or group dynamics) underpin Guattari's psychosocial relations to transversality through collectives and institutions such as political parties and state-run organisations. I shall explore how *group therapeutics* can provide a more fertile ground for the therapeutic act of uncovering and interpreting the exchange of messages between various groups in society and the individual unconscious. Additionally, how these messages are reflected in groups helps structure psychiatric hospitals and the broader social and political hierarchies and settings. I shall also explore how these dynamics relate to or resist the ideas of transversality and desire. This explication also explores how Guattari sees transversality operating through the interaction of group dynamics to reveal the unique singular personalogical (or *singularizing*) underpinnings of desire and its operation throughout society.

In parallel, I will investigate ideas related to transmission in the field of SRF, focusing on the nature of transmission systems, such as the physical transportation of electron signals from ECG machines. These transmission systems form the core pathways of connectivity that drive the human-robot interaction (or even the physical transmission of forces between the space of the hand and the robotic finger) and more theoretical ideas.

I bring together group transversality and transmission through the concepts of group dynamics, assessing their impact on the field of SRF. I also link the transmission of the semiotics of Guattarian subjectivity in group therapeutics, which helps produce the individual and apply it to the issues of SRF transmission in all its variations, including the transmission of epistemology. My critique of the physical systems aims to demonstrate how fixed ideas and the framing of semiotics and epistemology drive the field of SRF and science in general.

Chapter 4D - Using Fish Fins, the Otariidae Eared Seal flippers, and Playing the Piano with a six-fingered hand in the service of SRF innovation

In Chapter 4D, the dissertation investigates how various novelties in SRF research projects imbue the revolutionary potential within subjectivity for social change and openness through their innovations. The dissertation examines Guattari's critique of Marxist and psychoanalytic frameworks through the lens of *semiotic machines* and *coefficients of transversality*, analysing how these concepts manifest in SRF innovations while proposing a revolutionary approach to techno-subjectivity. It focuses on the desires of researchers and users in the pursuit of change, scientific advancement, and social change. I explore Guattari's critique of Marxism and the traditional forms of psychoanalysis via semiotic and semiological machines that have been overtaken by forces of capital, and how they have diminished *subjugated groups* (minorities and the working class) to bring about systems of enslavement. By changing the way we think, interact, and the dynamics of groups, Guattari proposes a new way for the working class to regain the institutional ability to effect change. This involves dismantling the horizontal and vertical dimensions of the pyramidal structure of modern social structures by introducing the concept of a *coefficient of transversality*. The coefficient of transversality is the sliding scale on which Guattari sees the metaphoric blinkers of open-mindedness in individuals, systems, and processes, which permit them to see others and value otherness. Through a detailed review of the various SRF innovations cited in Chapter 3, I aim to highlight their relevance for later discussion on subjectivity in this chapter. That is, I pinpoint the particularities of these innovations as examples for a more detailed examination and study how projects display high coefficients of

transversality, exploring how these projects achieve certain features and their effects in developing an innovative SRF design that can transform societal change.

By bringing together how coefficients of transversality appear in the field of SRFs, I endeavour to establish how Guattarian transversality may be an operative force for researchers. By placing the user at the forefront and centre of scientific and SRF production and by changing the paradigms to be more inclusive and cognisant of researchers' subjectivities and those they affect, I propose that the Guattarian approach to techno-subjectivity can be the engine for social and scientific innovation.

Chapter 4E - Desire to augment via transitional objects of transversality using Danielle (Dani) Clode's Third Thumb project

In Chapter 4E, the dissertation explores Guattari's object theory and its connection to transversality, examining how transitional objects, such as Danielle Clode's Third Thumb project, manifest the *new smoothness*- a conceptual space where technological innovation and human desire intersect to transform rigid societal structures into fluid, interconnected territories of becoming. I explore Guattari's ideas on how object theory, particularly transitional objects, functions in relationships between a range of entities, including persons, things, groups, institutions, and other structures, such as psychological, socio-political, and economic structures. Through psychoanalytical theory and processes, Guattari extends this notion to encompass the messaging systems and ways of viewing object-subject relationships. Their transformation has an impact on the unconscious, intersubjective, and intrasubjective effects.

Herein, I will bring together the various conceptual qualities of transversality and object theory to explain what Guattari means by his idea of the new smoothness. The new smoothness fosters a society that is open, free-flowing, and deeply interconnected, where individuals are free to pursue their own interests while being ethical and acting in accordance with their own desires. In the wake of transversality, we can think of the new smoothness as a social, psychic, and political condition that emerges when transversal processes break down the stratifications of rigid systems, creating new, fluid spaces of subjectivity and collective organisation. This new smoothness involves a micropolitical revolution of subjectivity that deterritorialises institutions and allows a shift toward collective, non-hierarchical modes of expression, where meaning is produced through the transversal interaction of different elements (individuals, machines, signs, materials) rather than being fixed in rigid, stratified systems.

I explore Danielle Clode's Third Thumb project and discuss how objects of desire and the new smoothness operate through her other work and the projects in which she collaborates with her other colleagues. I set out to uncover the implications of her work on subjectivity through one of her users, Kelly Knox, who positions herself in the process of becoming something more than a disabled body. Knox's example is a grounding material illustration of how Guattarian theory of transversality is applied in an everyday understanding of the explications in this dissertation, demonstrating how *techno-subjectivities* operate. Objects such as the Third Thumb emerge from our desires into the territories of imagined and real transitional objects, transforming relationships between the organic, inorganic, technological, and psychological to transfigure societies and their institutions into more inclusive and open spaces.

Chapter 5 - Conclusion

The conclusion summarises the dissertation and poses a range of ideas covered in the *Molecular Revolution in Brazil* as a means to rethink the field of SRF, considering its challenges, its impacts on its intended users, and their possible futures within the context of broader societal discourse. The object of this dissertation is no longer just a prosthetic but is at the forefront of human futures, where technology in the form of an SRF technics in the order of the kind of a third-thumb can transfigure subjectivity and its meaning for the individual, as well as its relation to the political dynamics of the collective that confound social progress and our social divisions. The discourse ceases to speak about subject-object relations. It opens up on Guattari's understanding of subjectivity and its extension into human the technics of augmentation, hence techno-subjectivity and its reconsideration of architecture.

Select Bibliography

A selection of references used throughout the dissertation and bibliographic background sources that helped shape this dissertation.

Appendix 1 - Scope and definitions from the introduction

Several definitions that might assist the reader with this dissertation are provided as part of Appendix 1. Whilst some of these terms will be well understood by the reader already, some of the key terms defined may also help delimit the scope of the dissertation.

Appendix 2 - A perspective on the evolution of the human hand

A tracing of the history of the evolution of the hand, as proposed by Jon Napier, its relevance to society and evolution.

Appendix 3 - Four noteworthy reviews, its evolution, and its relevance to technology.

A note on four noteworthy reviews that helped shape and structure the exploration of SRFs in this dissertation is provided.

Chapter 2 - Rolnik and Guattari's ideas on subjectivity

Introduction:

This dissertation brings together two disparate domains of thought and research: the ideas of the psychoanalysts Suely Rolnik and Félix Guattari on *subjectivity*, and the field of Supernumerary Robotic Fingers (SRF). This chapter will commence the task of examining Rolnik and Guattari's concept of subjectivity through their 2008 book, translated into English, *Molecular Revolution in Brazil*[32]—this book was first published in Portuguese in 1982. Before proceeding, however, I will briefly reflect on a lecture by Rolnik that serves as the basis for her book, *Spheres of Insurrection: Notes on Decolonizing the Unconscious* (2023), which significantly extends her understanding of subjectivity.[33] This work helps ease a reader into the former work, *Molecular Revolution in Brazil.*

This chapter focuses on extracting specific features of subjectivity as presented by Rolnik and Guattari. In short, the objective of this chapter is to extract the logics of *subjectivity* as understood by the two psychoanalysts. The term subjectivity has a very specific meaning that can be both simple and complex. The unfurling of their definition will take us through many concepts. This chapter shall highlight several thematics that shall be valuable in discussing the intersection of subjectivity and the third-thumb: I shall extend the exploration of subjectivity to concepts such as *schizoanalysis,* the *machinic, groups therapy (subject-groups and subjugated groups* to a lesser extent, how *minortitarianism* or *minorities* work*), transversality, revolution via aesthetic creativity,* the *new smoothness* and a conclusion on *transversality*. I explore these ideas because they have a profound effect and heft that leads to *active micropolitics* (that is, the micropolitics of subjectivity and the subject). These themes revolve around and relate to the overall arching idea that is reoccurring throughout this and other works of Guattari, and that is *transversality*, which is an umbrella-like idea that describes how different realms of experience and social domains intersect and influence each other rather than remaining separate, with a direct impact on the subjectivity of *minoritarianism* or *minorities*—those groups operating outside dominant power structures. Transversality and its related subthemes possess intensities that lead to active micropolitics, meaning the capacity for creative resistance and transformation through small-scale actions and expressions that challenge established systems.

[32] Guattari, *Molecular Revolution in Brazil*, 1.
[33] Suely Rolnik, *Spheres of Insurrection: Notes on Decolonizing the Unconscious* (UK: Polity Press, 2023).

This review will carefully elaborate on how Rolnik and Guattari encapsulate subjectivity and the subtleties of their art of *subjectivation*. Due to the complexity and subtleties of their definition, this section is necessarily lengthy and requires the reader's patience to appreciate the profound depth of their (re)definition. Their approach fundamentally challenges commonly understood notions of subjectivity by refusing both personological universals and structuralist reductions, instead proposing subjectivity as a processual multiplicity that emerges through heterogeneous components and *collective assemblages of enunciation* (for now, these can be thought of as multiplicitous, emergent assemblages of voices that make pronouncements about subjectivity).

A lecture by Suely Rolnik on subjectivity

Before I begin my analysis of their book *Molecular Revolution in Brazil*, I would like to briefly summarise a lecture delivered by Rolnik at the Saas-Fee Summer Institute of Art (SFSIA), Paris, 2020.[34] The content of this lecture has been inspired by Rolnik's original work in Portuguese titled *Esferas da insurreição: notas para uma vida não cafetinada,* originally published in 2018 and later altered and translated into English in 2023 as *Spheres of Insurrection: Notes on Decolonizing the Unconscious.*[35]

Rolnik asks her audience to picture a person caught between two powerful forces. On one side, there's society's rigid structure—think of it like a grid that shapes how we're supposed to think, feel, and behave. On the other side, there's something more primal and fluid—what Rolnik calls our 'vital forces,' those deep inner energies that make us truly alive. Now, Rolnik tells us something fascinating about this dynamic. She says these aren't really separate things at all. Using the image of a Möbius strip—that twisted band where the inside becomes the outside in one continuous surface—she shows how our personal expression and these vital forces are actually part of the same thing.

To illustrate this, she points to the Guaraní people of South America. For them, soul and language aren't separate—they're the same thing, nestled right there in the throat. When something goes wrong, it's because they have been pulled apart. The healing comes from bringing them back together. But here's where things get interesting for Rolnik. When the pressure between society's

[34] Suely Rolnik, "Suely Rolnik: Micropolitical Conceptual Tools for Decolonizing the Unconscious (Notes on Caring and Repairing Life)," in *Classroom*, ed. SAAS FEE Summer Institute of Art (www.artandeducation.net, 2020). https://www.artandeducation.net/classroom/video/350702/suely-rolnik-micropolitical-conceptual-tools-for-decolonizing-the-unconscious-notes-on-caring-and-repairing-life.
[35] Rolnik, *Spheres of Insurrection: Notes on Decolonizing the Unconscious*.

demands and our inner vitality becomes too much, our bodies send out what Rolnik calls a 'vital alarm call.' Think of George Floyd saying, 'I can't breathe'—that wasn't just about physical breath, but about life itself being suppressed. When this happens, we can respond in two ways, suggests Rolnik. We might embrace what she calls 'active micropolitics'—creating new forms of expression through art, poetry, or other creative acts. Or we might fall into 'reactive micropolitics'—trying to alleviate our discomfort by consuming more or projecting our pain onto others. What makes this whole dynamic so urgent, explains Rolnik, is that today, modern capitalism has created a system that constantly pulls us away from our vital forces, pushing us toward endless consumption instead of genuine expression. It's like we're being offered a feast when what we really need is to sing our own song. What Rolnik ultimately suggests is that we're not fixed beings but 'processual subjects'—always in the process of becoming. The challenge is to maintain our connection to those vital forces, even as the world attempts to categorise us within its predetermined boxes.

Molecular Revolution in Brazil

Some forty years earlier, Rolnik produced *Molecular Revolution in Brazil* with fellow psychoanalyst Guattari. This text is both a historical document and an experimental exploration of subjectivity. As Guattari himself frames it: 'This book is more a kind of travel journal than a work of philosophy, psychoanalysis or politics... These fragments, blocks of ideas, confidences, snippets of conversations, of letters, of conferences [...] aim to break loose from the individualization of enunciation.' [36] The book documents various movements and struggles that emerged in Brazil around 1982, following centuries of colonial rule. Rather than being a traditional academic text, it serves as a diagrammatic exploration of how different forms of subjectivity (what Rolnik would later call 'vital forces') can be freed from dominant systems of control. The work outlines how capitalism and political forces compete to control desire and the unconscious while also revealing paths of resistance through collective understanding and action.

The authors' approach is experimental and evolving, aiming to uncover connections between ideas and ways of living that exist beyond conventional modes of expression. It particularly focuses on *micropolitical* and *molecular* (small-scale actions of subjective resistance) aspects of subjectivity, emphasising collective experience over individual isolation. The text's significance lies in its practical approach to understanding how minorities and marginalised groups can defend and secure their

[36] Guattari, *Molecular Revolution in Brazil*, 1, Opening inside cover

voices against dominant forms of subjectivation, making it both a historical record and a toolkit for ongoing struggles. The ideas of the *Molecular Revolution in Brazil* are introductory yet complex extensions of real-world experimental applications of Guattari's life work and what would become of Rolnik's activism. They lead us through the trajectories to freedom of varied forms of subjectivity in a real-world way, not a utopic vision of new world orders. It may be helpful to pause to read the full quote which was initially relegated to the back cover of the first Brazilian edition of this book, and now sits on the very first page. It is a cautionary note from Guattari accompanying its authors' intent and its contextual value:

> This book is more a kind of travel journal than a work of philosophy, psychoanalysis or politics. Suely wrote it after we went through Brazil on the lookout for individuals, groups, intensities and desires coming our way. These fragments, blocks of ideas, confidences, snippets of conversations, of letters, of conferences – Suely's montage of words, mine, hers, of so many others – aim to break loose from the individualization of enunciation. They are a declaration of love for the intelligence and the collective sensibility of that country.[37]

Written by Rolnik with recorded conversations and commentary by Guattari, the book's 'status as a historical document'[38] captures the proliferation of the politics of the distinct groups and people with their particular viewpoints outside the mainstream resistance that emerged at the time and since the Revolution in Brazil in 1982. The book traces the various movements through *subjectivity* that result from the struggles against the overwhelming dominant forces overtaking the revolution in Brazil. The rapid overthrow of nearly five hundred years of colonial rule and constructed politics of subjectivation in a 'period in which regimes of exclusion and segmentation— colonial, slave-holding, dictatorial and capitalist'[39] formulated Brazil's dominant politics. The paroxysm sees the emergence of smaller, diverse struggles for reconstitution and recognition of minorities and the marginalised.

Most academics with worldviews may seek to be critical or use this book as a focus for launching points for political or, in terms specified here, *micropolitical* or *molecular* expositions or underpinnings for epistemic academic arguments. There is evidence that this was not the purpose of this book. The terms micropolitical and molecular, in relation to our personal hinge point of subjectivity, unravel in this book into a collective way of understanding it as something more and beyond individuality. The point is not to take the transcripts between Guattari and his interlocutors as a Platonic or Aristotelian travel almanac but rather as experiments in time and space. It is a diagrammatic tracing, a way of escaping the dominant modes of expression, frames, and perceptual

[37] Guattari, *Molecular Revolution in Brazil*, 1, Opening inside cover
[38] Guattari, *Molecular Revolution in Brazil*, 1, p12.
[39] Guattari, *Molecular Revolution in Brazil*, 1, p9.

modalities of the worldview on subjectivity in the here and now, one that draws it out from the unconscious into a free territory of relationships. Capitalism and desire compete to control our unconscious, our bodies, and the political landscapes in which we place ourselves. Here is an arms race for the rheostat of such territories.

Subjectivity

Rather than an individual inner essence or psychological interiority, Guattari conceptualises subjectivity as a collective and plural production—the 'ensemble of conditions which render possible the emergence of individual and/or collective instances as self-referential existential Territories, adjacent to, or in delimiting relation with an alterity that is itself subjective.'[40] Subjectivity is always manufactured and modelled by social, technological, *semiotic* and *machinic* processes; it is neither a stable structure nor a fixed possession but an open-ended, heterogeneous assemblage constantly being produced at multiple levels. This production occurs through various components: pre-personal affects, social relations, material environments, language, media, economic forces, and institutional practices. Guattari emphasises that subjectivity has a fundamentally non-human dimension that precedes individual consciousness, with *machines* of all types (technical, aesthetic, social) participating in its creation.[41] The aim of his *schizoanalytic* (an alternative concept to psychoanalysis that is broader and inclusive of such diversity) approach is not to interpret subjectivity but to foster the 'process of singularization'[42] (free from modelisation of the individual) that resists the standardising effects of capitalistic subjectivity and enables new forms of existential self-valorisation.

A factory of serialised subjectivity

When Rolnik and Guattari discuss subjectivity, they are simultaneously referencing politics (or *micro-politics*). Rolnik opens the discussion on micropolitical expression (the personal politics of subjectivity) as the territories where the unconscious is the target focus. This seems obvious, given her training as a psychoanalyst. She is clear that this is 'not just of material economics but also of the economy of desire'.[43] Rolnik introduces the nexus of micropolitics, which involves the liberation of unconscious desires, meaning that the unconscious serves as the store and emanator of all desires for life. For Rolnik and Guattari, the irreconcilable understanding of the schizoid power relations

[40] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p9.
[41] Guattari, *Molecular Revolution in Brazil*, 1, p43.
[42] Guattari, *Molecular Revolution in Brazil*, 1, p23.
[43] Guattari, *Molecular Revolution in Brazil*, 1, p15.

produced in capitalism always commandeers desires—it plunges the subject into a state of crisis because of its inability to adequately respond to the unconscious.[44] The subject is constantly adjusting to reestablish itself in equilibrium, balancing the schism and contradiction that capitalism has produced. This is typified in the way some things are acceptable at times and in certain places, but then suddenly become unacceptable when it's no longer convenient. An example of recessions and the behaviour of the capital market that causes them, and the various central banks that precipitate them, along with their irreconcilable lack of social and ethical predispositions. It forgoes, overrides and overcodes the actuality of the material pain it causes individuals, its actuality of experience and its experience of affect (the fundamental trigger that brings the desire to the fore), embodied, felt, yet repressed, forsaken at the mercy of effective mechanistic forces of capitalistic markets, which act on subjectivity to commandeer the body into lines of graphs, charts and numbers in the labour market—the depersonalisation using graphs and charts that we constantly hear and see in the news media. The body becomes an embodiment within a 'powerful factory of serialised subjectivity'[45] produced by such a capitalist system of sameness of 'individuality' shaped by consumption, economic and social divisions and classifications. The victim now becomes the consumer who is supposed to pull the economy out of recession through consumption. They become numbers in a game. They stipulate that there must be a substantial number of unemployed individuals before the markets (and inflation) can operate at their most effective.

For Rolnik, any crisis within this regime always brings fear of marginalisation and hardship for those who do not fit into the serialised individuality. In an attempt to survive obliteration at the risk of marginalisation, the subject seeks conformity through submission to a serialised version of dominant norms of labour subjectivity. It must yield to automated indoctrination models that articulate preconfigured desires into organised identities (individual identitarian islands of classification) based on an assembly line of pre-moulded ideas of personhood within the capitalist *semiotisation machinery*. The way it frames and shapes identities is based on being either a professional, a blue-collar worker, or one of the various dominant subjectivities it produces for us.

Rolnik and Guattari mention this *semiotisation machinery* because they assert that the mediating system for reaching the unconscious is through the ability of capital to work semiotically, signify, and transform the idealised form of capitalistic subjectivity. A system of references, values, and signifiers that personifies, codes personality, while any divergence codifies guilt, shame and responsibility upon the subjects through the collective unconscious, especially if it doesn’t conform to the labour

[44] Guattari, *Molecular Revolution in Brazil*, 1, p15.
[45] Guattari, *Molecular Revolution in Brazil*, 1, p16.

and religious laws of capitalist subjectivity. Rolnik and Guattari refer to this guilt-induced collective punishment, which is reflected inward on subjectivity, as *culpabilisation*. They suggest '[c]ulpabilization is a function of capitalistic subjectivity'.[46] This concept is important because these psychoanalysts see the notion of culpibalisation as directly related to the castration complex,[47] the Freudian notion of punishment for non-conformity. You will be punished for not conforming to societal norms. Marginality and minority are always at risk of the castration complex. The process of *singularization*, which Rolnik and Guattari introduce to us, is part of the micropolitical assemblages' process of escape.[48] The *singularizing* formation through micropolitical activism works in opposition to capitalistic subjectivity. It runs on the rails of assemblages of granular seeds of hope shaped through desires to become a fully self-styled relational subject based on its coordinates of what those desires mean for the subject and how they help relate to others. This process (*singularization*) of investment harnesses hopes and creativity for world-making as part of various formations shaped from untold possibilities—the type of potentialities that centre upon its localised political effectivity and coordinates of its interactions.

The book *Molecular Revolution in Brazil,* as mentioned, is an assemblage of 'block[s] of ideas'[49] and 'fragments of conversations, debates, discussions, interviews, round-table talks, and letters'[50] and fragments of essays. They are the reiterations of strategies of enunciation that are the 'strategies of desire in the social field'[51] as an active example in the formations of Guattarian and Rolinikian (to coin the term) micropolitical engagement, processes for cultivation and interventions for individuals and collectives. These are all but some of the 'strategies of desire in the social field'[52] that these two psychotherapists call 'micropolitics.'[53] To sum up her ideas, Rolnik indicates later in the book that the '*process of singularization*'[54] is the *raison d'être* of the molecular revolution. It is the underlying concept of this whole book. As Rolnik suggests:

> a way of rejecting all these modes of preestablished encoding, all these modes of manipulation and remote control, rejecting them in order to construct modes of sensibility, modes of relation with the other, modes of production, modes of creativity that produce a singular subjectivity[55]

[46] Guattari, *Molecular Revolution in Brazil*, 1, p55.
[47] Guattari, *Molecular Revolution in Brazil*, 1, p428.
[48] Guattari, *Molecular Revolution in Brazil*, 1, p51-52.
[49] Guattari, *Molecular Revolution in Brazil*, 1, p18.
[50] Guattari, *Molecular Revolution in Brazil*, 1, p18.
[51] Guattari, *Molecular Revolution in Brazil*, 1, p19.
[52] Guattari, *Molecular Revolution in Brazil*, 1, p19.
[53] Guattari, *Molecular Revolution in Brazil*, 1, p19.
[54] Guattari, *Molecular Revolution in Brazil*, 1, p23.
[55] Guattari, *Molecular Revolution in Brazil*, 1, 23.

Minority, marginality, autonomy, alternative

Rolnik introduces us to a series of key terms that Guattari uses when referring to subjectivity, and which are the focus of the concepts explicated throughout the book, which are also 'ruptures with […] capitalistic subjectivity'[56]: it is left to Guattari to explain the terms below:

> *1) 'molecular revolution' corresponds more to an ethico-analytico-political attitude (the same is true for 'function of autonomy').*
>
> *2) 'process of singularization' would be the more objective event of a singularity detaching itself from layers of resonance and causing the process to proliferate and broaden, which may or may not find an intrinsic structure or system of reference.*
>
> *3) 'Autonomy' refers more to new territories, new social refrains.*
>
> *4) 'Alternatives' can be either macropolitical or micropolitical.*
>
> *5) As for 'minority' and 'marginality,' I see 'minority' more in the sense of a becoming, a becoming-minority (examples: a becoming-minority for literature, which would be an escape from the dominant redundancies, a becoming-child, a becoming-crowd, etc.), while 'marginality' would be more sociological, more passive.*[57]

Let me explain these five key concepts from Guattari in clear terms, while maintaining their theoretical sophistication and tenets. It is important to do so to place the concepts in the frame of the *Molecular Revolution in Brazil,* in particular, and such terms will be important in later chapters of this dissertation, where they will be deployed:

'Molecular revolution' operates as an ethico-analytico-political stance rather than just a theoretical concept. It refers to a way of approaching politics, ethics, and analysis that focuses on micro-transformations and subtle shifts in power relations, as well as within our own subjectivities. Think of it as a mindset or attitude that enables us to detect and foster small but significant changes that have ripple effects.

The 'process of singularization' describes how unique events or phenomena break away from dominant patterns and proliferate into broader transformations, culminating rich, self-determined, unique subjectivities. It's about tracking how singular occurrences can evolve into broader changes, regardless of whether they align with existing frameworks or systems.

'Autonomy' specifically relates to the creation and emergence of new territories and social expressions. Rather than just independence, it's about carving out novel spaces for collective

[56] Guattari, *Molecular Revolution in Brazil*, 1, p171.
[57] Guattari, *Molecular Revolution in Brazil*, 1, p172.

existence and developing new ways of being together socially. Autonomy, thus, is part of the process that proceeds the latter two processes.

'Alternatives' operate on both macro and micro levels; they can manifest as large-scale political changes or as subtle shifts in daily life and personal relationships. The key is that they offer different possibilities to dominant models. Ideally, autonomy and alternatives work hand in hand in the processes of emergence from molecular revolutions, transversality, and their ultimate manifestation in the voices that arise from subjectivities within collective assemblages of enunciation.

The distinction between 'minority' and 'marginality' is crucial: 'Minority' is an active becoming or transformation (like literature developing new forms that escape mainstream conventions). In contrast, 'marginality' describes a more passive sociological state of being on the edges of society, helpless and held captive by their circumstances.

These concepts work together to help us understand how social and political change occurs through both small-scale transformations and larger, systematic shifts while maintaining a focus on concrete processes rather than abstract theories. Guattari distinguishes between 'marginalities and minorities'[58] and this distinction is important for he places them on a spectrum or, as he calls it, a 'waveband'[59] of a type of self-sufficiency. While minorities choose to identify themselves, the marginalised fall into a grid of state control, which he likened to Foucault's '*Surveiller et punir* (watch over and punish [otherwise known as *Discipline and Punish*])'.[60] The idea is that the marginalised fall into the hands of the dominant process of production of subjectivity by the mere fact that they are required to adhere to 'more totalitarian'[61] conformities of the welfare state institutions, where segregation is a mode of patriarchy, 'controlled, watched over, and assisted in [developed] societies'[62].

Schizoanalysis

Schizoanalysis emerges as a radical departure from traditional psychoanalytic practice, fundamentally reimagining how we understand subjectivity through desire and social

[58] Guattari, *Molecular Revolution in Brazil*, 1, p173.
[59] Guattari, *Molecular Revolution in Brazil*, 1, p174.
[60] Guattari, *Molecular Revolution in Brazil*, 1, p173.
[61] Guattari, *Molecular Revolution in Brazil*, 1, p173.
[62] Guattari, *Molecular Revolution in Brazil*, 1, p173.

transformation.[63] Unlike psychoanalysis, which roots itself in neurosis and operates through transference and interpretation, schizoanalysis takes its inspiration from the study of psychosis and refuses to reduce desires to personological systems, rather looking to the broader social-political environment.

The core of schizoanalytic practice lies in what Guattari and Rolnik call 'the art of cartography of desire'[64] - a micropolitical flair for detecting movements of social vitalisation, whether tiny everyday gestures or extensive social movements. This cartographic approach maps the flows, blockages, and potentialities within the politico-libidinal economy of social life. Schizoanalysis operates through what they term 'schiz' - systems of cuts that are not mere interruptions but intersections of processes that bring a new investment of potentiality.[65] The schizoanalytic unconscious is *machinic*, participating in formations of meaning that operate on staggered levels: vectors of meaning, paradigmatic relations, and synapses of affect and effect. The political dimension is crucial. Schizoanalysis works to dissolve frozen images and territorial rigidities that obstruct movement and prevent the creation of new territories of life. This dissolution enables what Guattari and Rolnik call 'processes of singularization'[66]—the emergence of new forms of subjectivity that resist the homogenising forces of what Guattari terms 'Integrated World Capitalism'[67] (IWC).

In the Brazilian context, schizoanalysis becomes particularly relevant as a tool for understanding and facilitating molecular revolutions—those micro-transformations that challenge dominant modes of subjectivation and open possibilities for new ways of being and operating society. The method recognises that behind the appearance of individuated subjectivity lie real processes of subjectivation that can be mapped, understood, and potentially redirected.

The schizoanalytic unconscious

The key idea is that Guattari and Gilles Deleuze propose a new way of understanding the unconscious processes of subjectivity that go beyond traditional psychoanalysis (Freud and Lacan).[68] Instead of focusing on individual therapy and family dynamics, they look at how broader social and

[63] Defined here by Suely Rolnik in 'Notes about certain concepts' in Guattari, *Molecular Revolution in Brazil*, 1, p470.
[64] Guattari, *Molecular Revolution in Brazil*, 1, p431.
[65] Guattari, *Molecular Revolution in Brazil*, 1, p470.
[66] Guattari, *Molecular Revolution in Brazil*, 1, p23.
[67] Guattari, *Molecular Revolution in Brazil*, 1, p477.
[68] Guattari, *Molecular Revolution in Brazil*, 1, p361.

collective forces shape our inner worlds and sense of self. This is a complex theory, and I will attempt to explain it as concisely as possible here.

Guattari and Deleuze's conception of schizoanalytics has diffuse schemas that extend to psychoanalysis. It moves beyond Freudian and Lacanian orders of 'oral performance, generally on a certain familial way of being of subjectivity'[69] and healing through affectual manifestations and interpretations between the two interlocutors of analyst and analysand. In the schizoanalysis of Deleuze and Guattari, they instead make an effort to incorporate and mobilise universal collective coordinates of issues that can deliver what they call '*subjective formations of becoming*'.[70] A self-styled person. A type of process of self-making, a type of self-evolution. Even though Guattari posits, in one section of *Molecular Revolution in Brazil*, that '*it abandons the terrain of signifying interpretation for that of exploration of assemblages of enunciation,*'[71] he doesn't mean to throw the baby out with the bathwater. He is seeking the utterances of enunciation that manifest and break down the meaning of their contextual issues. Pronunciations that bring light to a complex matter. In the same fashion, he downgrades the importance of the signifiers, but he doesn't abandon them altogether. He also reduces and transforms the systems of Freudian 'energetics,' instead very carefully negotiating what he calls '*levels of consistency of energy*'[72] between 'the energy quanta related to the consistency of their interrelations (actual and virtual) can only be discerned through the complex assemblages that they semiotize.'[73] This means that he places semiotics and energy upon a single processual plane of imminence. For this argument, he establishes a clear lineage (or model) of philosophical pretext that goes back to Leibniz's 'Monads'[74], and Michel Serres's 'myriads'[75]. A lineage that all notions rest on assemblages that invoke the concept of 'plane of immanence'[76] on which all levels of energy pulsate along. This is why he lauds Charles Sanders Peirce's 'phanersocopy'[77] and Louis Hjelmslev's 'glossematics'[78] so much because he sees such systems as conceiving 'a fundamentally "immanentist" perspective in the formation of

[69] Guattari, *Molecular Revolution in Brazil*, 1, p395.
[70] Guattari, *Molecular Revolution in Brazil*, 1, p395.
[71] Guattari, *Molecular Revolution in Brazil*, 1, p395.
[72] Guattari, *Molecular Revolution in Brazil*, 1, p397.
[73] Guattari, *Molecular Revolution in Brazil*, 1, p397.
[74] Guattari, *Molecular Revolution in Brazil*, 1, p397.
[75] Guattari, *Molecular Revolution in Brazil*, 1, p397.
[76] Guattari, *Molecular Revolution in Brazil*, 1, p397.
[77] Guattari, *Molecular Revolution in Brazil*, 1, p398.
[78] Guattari, *Molecular Revolution in Brazil*, 1, p398.

subjectivity'.[79,80] That is levelling everything out to give equal importance to informal voices and the formal semiotics and their processes.

Schizoanalysis and desire as production

Guattari attempts to explain that he and Deleuze sought to distinguish the idea that subjectivity and desire are synchronously entwined in a process that encompasses collective circumstances, which may sometimes be focused at an individual level. However, it is mostly about the 'interaction of individual facts on the collective level'.[81] Therefore, it's a misnomer, he says, that desire is a unique phenomenon in a separate island of knowledge, as found in current models of the subjective psyche.[82] These ideas that Guattari has referred to and previously described circumscribe the individual while dismissing relations to its context, relationships to other sources of subjectivity, and various economies in which it participates. Guattari refutes these modelised modes of apprehension and is specific in saying that these modes of apprehension tend to create versions of ourselves that we know as what we term the 'individual'. He insists it is '[a] phenomenon of serialization or identification'[83] which lends itself to manipulation by culture, identity and all the other facilities through which the grid of control of '*the production of capitalist subjectivity*'[84] tends to operate and produce the notion of individuality. Guattari narrows this understanding even further to the point of focusing on the '*pragmatics of processes of production of desire*'.[85] The pragmatics relates to all the contextual references in capitalistic societies, or those of fascistic, dogmatically driven, hierarchical societies that drive the individual into a corner through their contextual evocations of the concept of the self-contained island of the individuality and their very specified, circumscribed problematic relation to the collective and desire that manifests in segmented ways.

[79] In the foot note to this quote, "[a]ccording to Guattari, "despite the fact that Hjelmslev and the Linguistic Circle of Copenhagen rejected any possible translatability of the meaning of different systems of expression outside 'everyday language,' they intended to prepare a 'glossematic algebra' which, in their view, should be distinct both from the linguistics of spoken languages and from 'symbolic' logic."Guattari, *Molecular Revolution in Brazil*, 1, p493.
[80] Guattari, *Molecular Revolution in Brazil*, 1, p398.
[81] Guattari, *Molecular Revolution in Brazil*, 1, p343.
[82] Guattari, *Molecular Revolution in Brazil*, 1, p344.
[83] Guattari, *Molecular Revolution in Brazil*, 1, p344.
[84] Guattari, *Molecular Revolution in Brazil*, 1, p344.
[85] Guattari, *Molecular Revolution in Brazil*, 1, p344.

The machinic

Machinic unconscious

When it comes to negotiating Guattari and Rolnik's configuration of subjectivity, the idea of the *machinic unconscious* is important. The machinic unconscious is derived from something Guattari developed with Deleuze on the back of 'the concept of the "desiring-machine."'[86] Guattari stresses that the machinic unconscious is an elaborate 'machinic system' built on the concept of desire. Desire no longer becomes a separate fuel for the machine because desiring-machines are one and the same simultaneously. The machine is driven by desires, guiding its every motion and movement to express such affectualities. The machine is desire in and of itself. Guattari says, 'whereas desire appears as something undifferentiated that, according to the theories, could be attributed to an instinct, a drive or a raw force, and so on. I think that's completely false.'[87] In one fell swoop, Guattari is extricating himself from the Freudian axioms of energy, the second laws of thermodynamics, and the mathemes of the Lacanian unconscious, which he criticises.[88] He wants to free us from the models of thought that force us to think of the unconscious in a preconceived, modelled way, of wild, contrived signifiers from various disciplines that always crystallise a false image. His movement here is to displace us from our centralist ways of thinking by qualifying his concepts – 'I have my conception of the articulation of the various registers of these components, but that doesn't mean that I intend to propose them as a new system of modelization.'[89] The analytical process is the windfall of such arguments, for Guattari reinforces that the target of the 'molecular revolution'[90] must always be held to a type of process of verification and scrutiny. Its all about understanding and appreciating the analytical processes of the unconscious desire.

For Guattari, the molecular revolution in the analytical context is the establishment of a certain kind of thinking in terms of '"elements of the passage," of intersemiotic efficiency and also an inefficiency of passage, depending precisely on the systems that assemble them.'[91] This is a marked departure from the rigid grid that creates chandeliers of unconscious models inscribed in our institutions, our systems of politics, and the governance of the body, as well as through our egos and superegos.[92]

[86] Guattari, *Molecular Revolution in Brazil*, 1, p353-54.
[87] Guattari, *Molecular Revolution in Brazil*, 1, p353.
[88] Guattari, *Molecular Revolution in Brazil*, 1, p354.
[89] Guattari, *Molecular Revolution in Brazil*, 1, p355.
[90] Guattari, *Molecular Revolution in Brazil*, 1, p355.
[91] Guattari, *Molecular Revolution in Brazil*, 1, p356.
[92] Guattari, *Molecular Revolution in Brazil*, 1, p356.

Later, in *Molecular Revolution in Brazil*, Guattari expands on the idea of the machinic unconscious.[93] This time, he speaks of it in terms of the drives that bring the body into motion and emotion, which he prefers to refer to as 'affect'[94]. The term affect is a more accurate term for Guattari to describe emotions. This is because desire is often explained as the notion of undifferentiated energy or 'the economy of [..]drive infrastructure'[95]. Guattari proposes that we think in terms of an 'elaborated machinic systems'[96] of desiring machines as omnipresent and ubiquitous systems that describe all social systems we partake in. In that case, the theory of desire and drive becomes a single, intrinsic part of this system, always pushing or in pursuit of seeking connections with other machines that desire. Guattari extensively elaborates on this concept in *A Thousand Plateaus* (1980). It is a concept that he and Deleuze derived together. They developed this type of relationality machine and desire as a rhizomatic essence for the type of connectivity, so much a part of these desiring machines. We see from previous sections that the problem of splitting the concept of drive into both the Freudian and Lacanian systems produces a type of 'Manichean dichotomy between a supposed undifferentiated and *the* differentiated.'[97] Principally and more importantly, desiring machines rest on Spinoza's plane of immanence, already subscribed to by many poststructuralists, on which schizoanalysis hinges. So then it follows that '[s]ubjectivity is always taken in rhizomes, flows, machines, and so on; its always highly differentiated, always processual.'[98] This then highlights why Guattari sees the need for schizoanalytical processes, the machinic connections, to analyse these processually differentiated fields and landscapes of desiring subject assemblage that extend from the unconscious into consciousness and acts on life, and into their respective ecologies of performance and linguistics.

Group therapy—subject-groups and subjugated groups

For Guattari and Rolnik, subjectivity isn't formed in isolation within the personal islands of the individual; instead, it is shaped through the milieu of group interaction, where one becomes self-conscious of their laws, finality, and desires and uses these understandings to transform into a self-styled, singularized subject. Guattari suggests:

[93] Guattari, *Molecular Revolution in Brazil*, 1, p353.
[94] Guattari, *Molecular Revolution in Brazil*, 1, p406.
[95] Guattari, *Molecular Revolution in Brazil*, 1, p403.
[96] Guattari, *Molecular Revolution in Brazil*, 1, p403.
[97] Guattari, *Molecular Revolution in Brazil*, 1, p403.
[98] Guattari, *Molecular Revolution in Brazil*, 1, p404.

> What characterizes a process of singularization (which, at one time, I called the "experience of a subject-group") is that it is self-modeling. In other words, it captures the elements of the situation, it constructs its own types of practical and theoretical references, without remaining dependent in relation to global power, whether in terms of economy, knowledge, technology, or segregations and prestige that are disseminated. Once groups acquire this freedom to live their processes, they acquire an ability to read their own situation and what is taking place around them. It is this ability that will give them at least some possibility of creation and make it possible to preserve this very important character of autonomy.[99]

The key idea here is that this quote captures what Guattari sees as the fundamental difference between actual therapeutic transformation and merely repeating the same patterns: as a subject-group, there is a pathway towards becoming independent, free, and self-directed subjects. What he's getting at with the idea of 'self-modeling' is that a proper subject-group (or singularized individual) develops its capacity to understand and respond to situations and relate to them without having to rely on external authorities or experts telling them what to do. When Guattari talks about 'self-modeling', he describes what you could call the group's ability to 'read the room'—they develop this capacity to figure out what is happening in their situation without relying on outside power structures or pre-existing frameworks imposed on them. This is completely different from what he calls 'subjugated groups', which 'get manipulated by external determinations and end up being dominated by their own internal law (superego)'[100].

The therapeutic dimension emerges through what Guattari describes as the group acquiring 'this freedom to live their processes'.[101] This isn't just about people sitting in a circle talking about their problems—it's about the group developing what he calls 'an ability to read their own situation and what is taking place around them'.[102] The group becomes a kind of collective analytical apparatus that can detect and work with the flows of desire and meaning that are moving through it, rather than just reproducing conventional therapeutic models. This connects directly to his work at La Borde clinic, where he observed how therapeutic groups could become what he calls 'local centres for collective subjectivation'.[103] Instead of trying to fix individual pathology through standard psychological interventions, the focus shifts to creating conditions where new forms of subjectivity can emerge through what he terms 'multiple exchanges between individual-group-machine'.[104] The

[99] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[100] Guattari, *Molecular Revolution in Brazil*, 1, p471.
[101] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[102] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[103] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p7.
[104] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p7.

group becomes a space for what he calls 'processes of singularization'—ways of becoming that can't be reduced to standard psychological categories or predetermined social expectations.

The autonomy he suggests isn't just about political independence from external control—it comes to be more akin to what he calls 'autopoiesis', which is the capacity for self-creation and self-transformation that allows the group to maintain its creative potential while still engaging with external realities and constraints.[105] This means subject-groups (singularized subjects) can construct 'their own types of practical and theoretical references'[106] without becoming dependent on global power structures, whether these operate through economy, knowledge, technics, or various forms of social segregation and prestige systems.

Individuals as singularized (subject-groups) rather than cultural (subjugated group)

Rolnik's critique of culture highlights the problems associated with subjectivity that is framed and constructed through the processes of individuation (subjugated groups dominated by external authority), operating only within the lens of capitalism. The semiotisation, that is, the recursive construction of identity through signification and linguistic cues of personification, is the process that is the target of her focus. She believes its functions 'are standardized and capitalised to suit the dominant mode of semiotization – they are cut off from their political realities.'[107] This means that the modelled ideals used to shape individuals are moulded to suit the dominant systems' idealised by dominant systems of signification, which override and pull into their orbit the linguistic systems, syntactical structures, phonological elements, etymological biases, and so on that express idealised content and expression, dismissing real material issues and contradictions. In a debate with an indigenous Brazilian activist about Bahian racial identity, Guattari argues that cultural identity can be '*profoundly reactionary*'[108] as it reinforces binary thinking, preferring instead to 'speak of an *assemblage of processes of expression*'[109] that recognises both molar power relations (global forces) and molecular singularities. While acknowledging how cultural identity can function as resistance through ethnocentrism[110], Guattari points to how non-Western cultures like *Candomblé* demonstrate alternative, non-logocentric forms of expression that escape rigid identitarian logic and enable more fluid processes of singularization[111] (subject groups that are free to make choices).

[105] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p7.
[106] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[107] Guattari, *Molecular Revolution in Brazil*, 1, p21.
[108] Guattari, *Molecular Revolution in Brazil*, 1, p97.
[109] Guattari, *Molecular Revolution in Brazil*, 1, p97.
[110] Guattari, *Molecular Revolution in Brazil*, 1, p98.
[111] Guattari, *Molecular Revolution in Brazil*, 1, p98.

For Rolnik and Guattari, culture itself comes to look like an extension of the systems that work together in their concept of 'Integrated World Capitalism'[112] (IWC), which both authors characterise as 'capitalistic modes of production'[113] that seek to separate the political realities of subjective expressions through hijacking the process of subjectivity, of which semiotics is a key operator. They distinguish the *realpolitik* of the singular realm of the personological, which is free from domination.[114] A *realpolitik* that is local to the body, from the body, self-developed. This is opposed to and separate from the individualised models of the concepts of the self, which are modelled in capitalistic subjectivities received from the IWC systems that relate the body to production systems. The concept of *singularity* used here refers to the free personological subjectivity that is local, self-devised, social, and central to the ideas explored further by the two psychoanalysts throughout their book. This is the realm that Guattari refers to in his earlier works as the subject group. Still, for the sake of comprehension, to contrast this notion with individuality (the subjectivity of IWC found in the subjugated group), singularity might be thought of as a unique collection of the self and its relations, with varied and complex differences between individuals, making the personological unique and self-made. The complex combinations that a singularity brings together can form between the self and its relations to various systems, bodies, environments, ideas, and so on, which can lead to a full self-styled creation of the person without the limitations or constraints of the socio-economic influences and characterisations. The singular cannot necessarily be reduced to stereotypes or stratified references of individual identity, as subjectivity is not limited to such reductive notions. The individual identity described here is the process of IWC, not the process of singularization that Rolnik and Guattari wish for us. We shall see that Rolnik and Guattari extend this critique to include the psych sciences, which reinforce and perpetuate the process of individuation. The individual is a ready-made idea of the person, manufactured from the components constituted and formed by politics, far removed from its everyday imperatives, and reproduced as signifiers and the signified in its portrayal, situated in linguistics, as well as its visual portrayals of stereotypes. It is a characterisation used to commodify values meted out, with codified references in economic terms for measuring and giving meaning to exchanges, in clinical and remote ways that have only meaning in market terms, with no regard for the desire of that singularity and its collective relations. Rolnik

[112] The term “Integrated World Capitalism” is one coined by Guattari to distinguishes the malfeasance of the the term “globalisation” which hides its true nature to hardness all vitality for the sake of economy, “because it tends to leave no human activity, no productive sector, outside its control”. Guattari, *Molecular Revolution in Brazil*, 1, p477.
[113] Guattari, *Molecular Revolution in Brazil*, 1, p331.
[114] Guattari, *Molecular Revolution in Brazil*, 1, p23,31,339.

and Guattari suggest '*It is the very essence of capitalist profit to not be restricted to the field of economic surplus value: it also resides in the seizure of the power of subjectivity.*'[115]

Guattari explicitly clarifies that singularity and the processes that lead to singularization are completely different to the concept of identity and its socio-historical formations. In his critique, he advises, '[i]n other words, *identity is what causes singularity to pass from different ways of existing to a single identifiable frame of reference*'.[116] Guattari positions singularization and individuation as interrelated but distinct processes, with individuation often restricting the full potential of singularization by pushing toward 'reductionist views in the field of phenomenology and psychology'.[117] He traces individuation back to basic biological drives. He argues it creates a prison of subjectivity through what he calls 'culpabilization'[118] - the burden of responsibility that links ego to social identity. In contrast, processes of singularization (becoming a subject group) operate beyond individual boundaries and modelising systems of identification, connecting with 'infrapersonal and extrapersonal'[119] dimensions that individuation typically represses.

Rolnik describes the individual's conception of the self as a commodity that is traded and marketed in the milieu of 'culture of equivalence'[120] or 'system of equivalence in the sphere of culture'.[121] This system serves as the foundation for integrating everything into a system of fiscal equivalence, with economic benefits or exploitation, depending on one's political perspective. Therefore, the macropolitical domain is the dominant system that standardises, deterritorialises, reterritorialises, codifies, and always controls the processes that capitalise on the production of culture, always orienting and reorienting all semiological meanings through controlled markets. And it does this through the system we call *culture*. That is why the two psychoanalysts find the notion of culture so problematic for the construction of subjectivity. Rolnik specifies that '[c]ulture is not merely the transmission of cultural information, the transmission of systems of modelization; it is also a way for the capitalistic elites to exhibit what I would call a general market of power'.[122] When I refer to Rolnik and Guattari's modelisation through classification, I am speaking of the systems that indoctrinate segregation via subjectivity according to hierarchical systems, assigning meaning and values (both moral and economic) whilst always creating territories for new cultures, capturing those who escape any redundancies (alternate subjectivities or singularities into new cultures) or

[115] Guattari, *Molecular Revolution in Brazil*, 1, p22.
[116] Guattari, *Molecular Revolution in Brazil*, 1, p94.
[117] Guattari, *Molecular Revolution in Brazil*, 1, p52.
[118] Guattari, *Molecular Revolution in Brazil*, 1, p52.
[119] Guattari, *Molecular Revolution in Brazil*, 1, p53.
[120] Guattari, *Molecular Revolution in Brazil*, 1, p21.
[121] Guattari, *Molecular Revolution in Brazil*, 1, p21.
[122] Guattari, *Molecular Revolution in Brazil*, 1, p28.

emergent subjectivities back into some new model. When new tribes or cultures are discovered, their anthropological and social value as 'archaic or precapitalist societies'[123] is always stratified to extract maximum value from their art and its ways of representation. Hence, the target of this production process is referred to as the individual because it falls into the well-prepared concept of selfhood, who is who, and how much they are worth—a self-perpetuating, prefabricated product of the markets of equivalence and cultural effects, as well as artefacts. Still, for now, we can see that the latter is a production of capitalistic modelisation found in psychoanalytical and psychological development, namely the concept of individuation from the cradle to the grave. This includes the familial psychoanalytical life and the working institutional life (and its equivalent labour life). Individuation is opposed to singularization, which is the creation of a self-styled personological formation based on the desires of the person that makes them uniquely different. This uniqueness stems from their ability to reference their experiences and environmental intersections, which are part of the ongoing, singular processual subject that constantly evolves through interaction.

Subjectivity and semiotics and their impact on subject-groups and subjugated groups

Semiotics plays a large part in the processes of subjectivity and becoming singular (working as a subject group) as opposed to being an individual trapped as a subjugated group, and can shift a group from one state to the other. For Rolnik and Guattari, subjectivity is closely linked to what is said, how it is said, and what it creates in terms of meanings and significations (through to the unconscious). These enunciations are gathered into an idea that foregrounds the two psychoanalysts' personification of subjectivity. Rolnik borrows heavily from Guattari, deploying the term '"collective assemblages of enunciation" […, a] collective assemblage [that] does not correspond either to an individuated entity or to a predetermined social entity'.[124]

What constitutes *collective assemblages of enunciation* can, at times, be rather vague. These are neither individuals nor social groups; rather, they are 'machines of expression'.[125] These can be any systems of organic, inorganic, what Rolnik refers to as 'extrapersonal, extra-individual […] infrahuman, infrapsychic, infrapersonal nature'.[126] Subjectivity is described as a process that relies

[123] Guattari, *Molecular Revolution in Brazil*, 1, p22.
[124] Guattari, *Molecular Revolution in Brazil*, 1, p43. Collective Assemblages of Enunciation are much more than mere utterances, they surpass the utterance of capitalistic individuation and are instead more than 'soley in the sense of a social group [or collective unconscious]; it also implies the involvement of a variety of collection of technical objects, flows of matter and energy, incorporeal entities, mathematical or aesthetic idealities' define Rolnik and Guattari. From Guattari, *Molecular Revolution in Brazil*, 1, p464-65.
[125] Guattari, *Molecular Revolution in Brazil*, 1, p43.
[126] Guattari, *Molecular Revolution in Brazil*, 1, p43.

on the decentering of the undertakings in the formation of an assemblage. This process would oppose the centered position of the semiotisation process of individuation of social and psychic productions—the fluidity by which the decentering process of an assemblage reorientation itself is expressed in its plurality and multiplicity of its micropolitics, which means that it considers the person(s) and their contextual relations, their structures of reference, needs for vitality and any creativity prior to contingency (particularly in language). To this point, I must stress that Rolnik and Guattari relate the linguistic and social character of language, as proposed by Ferdinand De Saussure, to how subjectivity is consumed or created between the 'transmitter and receiver'.[127] The disparities in how language is experienced are a result of structural disparities created by capitalistic structures and, indeed, structuralism's reification of them.

For Rolnik, subjectivity oscillates between alienation and expression. A subjectivity of 'alienation and oppression'[128] occurs when the individual submits to subjectivity (i.e. subjugated groups) as they receive and internalise its characteristics and representation because of their lack of power as a group, often representing the oppressed. However, the process of '*singularization*'[129] is when the individual can reappropriate characteristics of that subjectivity whilst mutating and placing itself in the intersection of experience and other determinations of various registers of subjectivity and otherness. This is the process of '*singularization*'[130] that one can argue is more readily available to dominant classes (subject groups), who have the power for such bold movements, giving them more opportunity to create landscapes of their own mutations that aren't easily overwhelmed, which can, on the flip side be later imposed on others through manipulation of the power of capital.

In essence, Rolnik disputes the duality of the current understanding of subjectivity given by structuralists. The idea that subjectivity is the intersection of language and communication. 'There is no "recipient" subjectivity in which external things are placed and then "internalized". These "things" intervene in the actual syntagmatic of unconscious subjectivation.'[131] Rolnik is making a crucial point about subjectivity and how it forms. She rejects the common idea that subjectivity is like a container that passively receives and internalises external experiences. Instead, she argues that elements from the outside world ('things') directly participate in and alter the unconscious structuring of subjectivity itself. Rolnik is challenging the inside/outside binary that assumes a pre-existing subject who then takes in external reality. This aligns with Guattari's broader theory that subjectivity is produced through assemblages rather than being contained within an individual psyche. The

[127] Guattari, *Molecular Revolution in Brazil*, 1, p46.
[128] Guattari, *Molecular Revolution in Brazil*, 1, p46.
[129] Guattari, *Molecular Revolution in Brazil*, 1, p46.
[130] Guattari, *Molecular Revolution in Brazil*, 1, p46.
[131] Guattari, *Molecular Revolution in Brazil*, 1, p47.

'syntagmatic of unconscious subjectivation'[132] refers to how unconscious elements combine and arrange themselves to produce subjectivity—and this process happens through direct intervention of external forces, not through a process of internalisation by a pre-formed subject. Think of it like this: Rather than being a bowl that gets filled with experiences, subjectivity is more like an ongoing chemical reaction where new elements completely transform the composition of the mixture. The external 'things' don't just get added to an existing subject—they fundamentally reshape how subjectivity itself is structured and produced.

Although both authors spend much of their time railing against the dominant semiotisation of capitalistic subjectivity, it is important to note here that Guattari concedes that semiotisation is a necessary part of subjectivity. 'A subjective fact is always engendered by an assemblage of heterogeneous semiotic levels',[133] however the rise of capitalism for Guattari is the over-coding of the vast heterogeneous landscapes of semiotic levels to the point where it is confined to a prison of signifiers of totality. Guattari cites the works of Philippe Ariès and Donzelot, which demonstrate that the delimitation of childhood subjectivity has shifted from clan-based, dynamic systems of social relations to a family-based system of reference over the centuries. This process creates islands of personhood, with little extant of relations to other subjective territories. This reductive subjective relation of cosmoses of choice and exposure to a relationship between mother and father is detrimental for Guattari. He even critiques Freud by saying, 'Freud always looked for references in ancient mythology, yet he translated them to a kind of family novel much closer to the work of Goethe.'[134] It resulted in the development of '[i]dividualized responsibility'[135] , cutting loose strong 'natural' relations to 'primary group systems'[136] like the clan. A system in which multiple subjective coordinates of variation nurture them and develop strong exchange links. Instead, it was supplanted by relations to property, 'laws of capitalistic subjectivity',[137] and moral laws where subjectivity is reduced to objects.

Minority experiments in the media help shift the subjugated groups into subject-groups

When thinking about how to encourage the flourishing of subjectivity through the processes of singularization— (that is, the free movement of subjugated to subject-groups), Guattari gives us a picture of how this can happen in practical ways. Guattari discusses the importance of the processes

[132] Guattari, *Molecular Revolution in Brazil*, 1, p47.
[133] Guattari, *Molecular Revolution in Brazil*, 1, 49.
[134] Guattari, *Molecular Revolution in Brazil*, 1, p49.
[135] Guattari, *Molecular Revolution in Brazil*, 1, p49.
[136] Guattari, *Molecular Revolution in Brazil*, 1, p49.
[137] Guattari, *Molecular Revolution in Brazil*, 1, p50.

offered by the minority experiments in free radio, which began in 1977 and continued into the period of the French presidencies of Giscard d'Estaing and Mitterrand. These experiments, as outlined in *Molecular Revolution in Brazil,* are worth recounting here because they help to contextualise a position in relation to technologies and the technics of the third-thumb discussed later in this dissertation. Guattari was a leading figure in the free radio movement, helping to foster the flourishing embryonic movement and spearheading a station he called 'Radio Tomate' (Radio Tomato). Optimistic about the potential free radio can offer, Guattari encourages experimentation with technologies in analysing and understanding something akin to free speech and the autonomy it brings. He cedes the real and material ways in which the subjectivation process of Brazilians can emerge to break free from the shackles of dominant control that curtail freedoms. Guattari seeks the emulation or, at the very least, a similar repetition of the types of experiments he experienced while trying to achieve equal access, citing the European examples he refers to during his activism. Thus, he refers to the Spanish, French, Polish, and Italian examples, where the people's resistance extinguished the unravelling monopoly over the airwaves held by those respective governments. This process unleashed the growing landscape of small radio stations, allowing people to express their desires, voices, utterances, and deep yearnings. In France, this led to the ossification of state-owned radio as a consequence and freedom from the dominant voices or hegemonic discourse and manipulation. At the same time, a burgeoning period of minority voices started to be heard across the country, from Saint-Denis (a Paris suburb) to the mountains of Alsace. According to Guattari, it is apparent that this freedom of expression allowed for 'contradictions between a model of predictable listening and this thing that people began hearing and that kept mutating.'[138] These mutations for Guattari are the essence of the rhizomic articulations in the processes that facilitate the emergence of singularization and assemblages of enunciation. They are rhizomic because they don’t have a start point and end point, but are constantly in a system of relations to their environment, like a plant's rhizome. As defined by Guattari earlier, the assemblages of enunciation are the collective systems or machines of expression. This mixture of collective enunciation and exchange helped develop different uses for radio, which meant different listening relations, habitats for feedback on various spoken styles of minor languages, and forms of expression that were often unheard of on the radio, allowing new forms of ideas to develop. Ultimately, with the extensive reach of government, it became inevitable that some levels of micro-politics of this free and unwieldy expression would be reappropriated through the regulation of FM and AM bandwidths, the exchange of financial support through a system of grants, and the establishment of quality codes and standards. Oddly, for Guattari, although not a capitalist overreach on this occasion, it became an

[138] Guattari, *Molecular Revolution in Brazil*, 1, p149.

example of a power grab by the state instead. In any case, the function of such an elaboration of small radio channels, he says, functioned to bring '*about sweeping away the dominant redundancies*, a certain way of speaking'.[139] Dominant semiotic forms of expression were broken by the bandwidth 'of syntax, rhetoric, and argumentation'[140] of and against 'dominant molds'[141]. Guattari references the example of Poland and its free radio movement, where resistance to an oppressive regime was spearheaded by clandestine broadcasts that 'reflect on the role of free radio in democratic organizations.'[142]

Reflecting on the micropolitical implications for subjectivity through literature, Guattari examines the essence of Kafka's work to demonstrate how the ability to 'capture in a statement something that initially seemed to him to be impossible to semiotize,' referring to the type of exchanges found on local radios. It is the fragmented work of Kafka that Deleuze and Guattari engage to articulate the concept of the 'minor'[143] language, attributed to describe a certain kind of expression of the local character—this notion of '"minor expressions" in the field of literary production'[144]. Guattari is describing an experimental and mutant language that breaks free from dominant linguistic codes and structures. It is key to appreciate that it is its transformational power and its direct affective character that imbues forces of micropolitical utterances in the process of subjectivation. Guattari elaborates further by extending this notion by saying, 'its precisely this singular, minor production, this singular point of creativity, that will have a maximum impact on the production of mutation of sensibility, in all the different fields that I call molecular revolution.'[145] Guattari reinforces his idea that minor language emerges through collective assemblages of enunciation.

In conclusion, the critical points that emerge from Guattari's theoretical framework can be synthesised as follows: It is rarely the case that a direct vector of elaboration circumscribes an analysis of the process mediated between the receiver and the producer of the image. Instead, the passage of information in the communication system depends on what sociologists have demonstrated to be intermediary systems called 'primary groups or "two-step groups"'.[146] These processes and procedures of elaboration impact public opinion and are the modelling groups of signifiers of reference used, which are the targets of capitalistic subjectivity and control. Thus, free radio is about reconfiguring these relations of daily life, expressions, and a sense of active sensibility

[139] Guattari, *Molecular Revolution in Brazil*, 1, p154.
[140] Guattari, *Molecular Revolution in Brazil*, 1, p154.
[141] Guattari, *Molecular Revolution in Brazil*, 1, p154.
[142] Guattari, *Molecular Revolution in Brazil*, 1, p156.
[143] Guattari, *Molecular Revolution in Brazil*, 1, p161.
[144] Guattari, *Molecular Revolution in Brazil*, 1, p161.
[145] Guattari, *Molecular Revolution in Brazil*, 1, p162.
[146] Guattari, *Molecular Revolution in Brazil*, 1, p170.

for the assemblages of reappropriation—a micropolitical move in the rhizomatic formation of a new process of subjectivation, freeing subjugated groups into the will of subject-groups.

Transversality

Minorities and rhizome

According to Guattari, given that the definitions of marginality and the process of marginalisation are said to be passive processes (as opposed to the becoming of minorities) brought about by the dominant system of production of subjectivity, the nature of becoming in minorities is hence the active centre for molecular change within societies. Guattari believes minorities tend to consider the 'problematics of unconscious subjectivity in the social field'[147] because they actively seek out the process that attempts to splinter impasses in the face of crisis, according to Rolnik. Rolnik continues the argument by stating that the creation of dialogue among oppressed groups is a process that fosters enthusiasm for questioning the entrenched status quo as they are compelled to seek reason. Rolnik thus concludes that the 'repressive modelization'[148] forces contained in international markets are subject to a double-edged sword. She asserts that they are both mechanisms for producing dominant subjectivity and relentless in creating new ones, such as those of minorities. Information markets often utilise the image-makers and economic markets with their inherent reach to quickly sweep across the entire planet as machines for the 'transmission of [new] sensibilities and experimentation[s]'[149] for minorities. This is the double-edged nature of their function, to both reach new territories quickly and spearhead ideas while simultaneously territorialising them through their capitalistic functions that model subjectivity.

The rhizomatic character that permits transmission and experimentation is a brief moment that emerges in this process of producing subjectivity, free from the grip of capital, for example, just before territorialisation sweeps over subjectivity. It is the rhizomics of new ideas that form part of the process that emerges due to 'minorititization'[150] permitting an '"alternative"[…] processual character'[151] free from ideology and paranoia, projection, or culpabilization, to enable a 'process of reflection and analysis, a complete *activity of metabolism of the change in the perception of*

[147] Guattari, *Molecular Revolution in Brazil*, 1, p174.
[148] Guattari, *Molecular Revolution in Brazil*, 1, p175.
[149] Guattari, *Molecular Revolution in Brazil*, 1, p175.
[150] Guattari, *Molecular Revolution in Brazil*, 1, p172.
[151] Guattari, *Molecular Revolution in Brazil*, 1, p177.

situations, which may lead to alliances.'[152] Within this brief moment of autonomy, these systems of alliances form, wherein lies the distinctive constitution of 'transversality'[153] at the heart of the process of singularization. This is a crucial point that this dissertation will revisit several times. The rhizomatic systems (with their branching multiple connections that don't follow straight lines) need certain guidelines that enable 'self-organization'.[154] These guidelines help evaluate how desire expresses itself and connects across different domains, manifesting in what Guattari calls *transversality*. Essentially, it creates a system that enables rhizomatic growth and development, guided by ethical principles and practical application, which is part of the ethico-analytico-political stance discussed by Guattari earlier.[155]

Minorities: the becomings of society

The process of becoming is gleaned in the ways of 'becoming-homosexual, [...] becoming-feminine[,...] becoming-black'[156] – the very process of becoming a minority. According to Guattari, within IWC, there is an inherent expression of an 'economy of desire that tends to question a certain kind of goal in the production of social relations'[157] outside of 'masculine subjectivity'.[158] IWC creates mechanisms of prohibition that stifle the production of intersubjectivity outside dominant phallocentrism, that is, the 'problematics'[159] that involve symbolic and material production that may interrupt its flows or interrupt the capital machine. Here, Guattari turns to Arthur Rimbaud as an example of the cultural production of 'ethnographic categories'[160] related to becoming black that has nothing to do with reifying capitalistic production systems; instead, it circumvents them. In these processes, the process of becoming is implicit in the process of singularization. That is, the process of singularization takes place outside dominant subjective production machines. For minorities, it is bound up in the 'problematics of multiplicity and plurality, rather than a question of cultural identity'.[161] Guattari suggests here that for minorities, there is a remodelling process that sits outside the stereotypes of identity-making systems set in motion by IWC. Rather, it flows from the

[152] Guattari, *Molecular Revolution in Brazil*, 1, p177.
[153] Guattari, *Molecular Revolution in Brazil*, 1, p177, p486.
[154] Guattari, *Molecular Revolution in Brazil*, 1, p177-78.
[155] Guattari, *Molecular Revolution in Brazil*, 1, p178.
[156] Guattari, *Molecular Revolution in Brazil*, 1, p101.
[157] Guattari, *Molecular Revolution in Brazil*, 1, p101.
[158] Guattari, *Molecular Revolution in Brazil*, 1, p101.
[159] Guattari, *Molecular Revolution in Brazil*, 1, p102.
[160] Guattari, *Molecular Revolution in Brazil*, 1, p101.
[161] Guattari, *Molecular Revolution in Brazil*, 1, p102.

inner personological construction of the self through self-discovery, experience and understanding of its situatedness through experimentation.

However, this becoming has what Guattari calls a *transverse process* or *transversality* at its heart that incorporates other modes of subjectivity. The concept of transversality is a significant part of this thesis and will be explained in detail in the five chapters that follow (in Chapter 4 series). For now, it suffices to say that transversality is a vector of self-actualisation that travels through all sets of experiences on which an open trajectory flows, picking up various sets of values and properties of that experience to form the singularized assemblage of subjectivity. Transversality and its mutations can incorporate the past (the revival of archaic identity), the present, and the dominant or distributed stratifications, as they detect 'subjective realities'.[162] This is significant because for a subject, it flings open the mental door of broadmindedness to all sets of experiences, knowledge, senses and conceptions of the world in the service of thriving beyond the limits of a grid on which an individual is modelled. Paradoxically, the concept of 'identity', the stratifying blocks of capitalism on which modelling occurs, is also a process that anticipates becoming. It can territorialise the 'corridor of passage, corridors of unconscious communications'[163] that is part of transversality with other such diasporas of becoming (which permeate different modes of subjectivation), especially that of becoming of other minority groups and can anticipate different subjectivities before they escape the clutches of IWC. This is an anticipatory mechanism by which IWC competes and strives to capitalise on all differentiation, incorporating it into the system of market values even before it emerges. The gravity of IWC reifies dominant subjectivity at the cost of singularization. For example, gay marriage was once excluded from systems of capital, denying the partner the rights of other heterosexual couples. Still, the milieus of capital soon territorialised and validated gay marriage by voting to include it within the bounds of other conjugal systems of matrimony, benefiting from the surplus monetary value it brought to large markets that cater for this subjectivity afforded to them through the rights and rituals of marriage.

Minoritarian subjectivity is the active movement in the process of 'unconscious communication',[164] on the road to becoming singularized, meaning they are seeking the mobility of concepts of struggle and resistance that will eventually form the singularized minoritarian subjectivity where one questions one's existence and, via the inventions of self-discovery, finds a course for one's life and one's subjectivities through one's desires. Therefore, Guattari suggests that questions are asked along the way of such confronting processes, where questions such as what it is to be black and

[162] Guattari, *Molecular Revolution in Brazil*, 1, p102.
[163] Guattari, *Molecular Revolution in Brazil*, 1, p102.
[164] Guattari, *Molecular Revolution in Brazil*, 1, p102.

what it is to be feminine or homosexual are asked. They are part of the progressions reaching outward in a single trajectory towards a mode of subjectivation, a process of opening up the inner self to the possibilities offered in the material world, a simultaneous one, according to Guattari.[165] Deleuze and Guattari refer to this process of elemental reconfiguration as the 'molecular dimension' of the unconscious.[166]

The process of marginalisation that occurs for minorities is a micropolitical process of singularization that has the potential for the transformation of the masses in its potent form. I suppose Guattari is suggesting here that marginalisation is a positive process in the birth of singular self-determined subjectivities, even though it can eventually become passive. In a brief moment, it becomes the starting point for the recognition and expression of resistance. A push back that permits the space for flourishing open subjectivities based on the concept of transversality.

Revolution and creativity

Revolution and aesthetic creativity are quintessential to Rolnik and Guattari in the experiments that lead to the emancipation of subjectivity, enabling free will, ethics, and social connection. Rolnik and Guattari guide us through the core of their perspective on subjectivity as the raw material of all productive systems, and how it can be reoriented to facilitate revolutionary change and the creation of a new order of social and civil engagement.

Subjectivity as raw material for production

Rolnik and Guattari question the very nature of what we have come to understand philosophically about subjectivity. The philosophical tradition of '*être là*'[167], 'To Be' or 'to be there', is in question for Guattari. That is the acceptance that things are what they are. So, I have to question: what does it mean to be? What is the subjectivity—to be? History has often treated subjectivity as a settled issue, as if it were a banal, static, and neutral state that is a given. Rather, Rolnik and Guattari immediately confront us with the notion that subjectivity is the one that emanates from industrial production, 'essentially manufactured, modelled, received and consumed'.[168] Rolnik and Guattari embark on a

[165] Guattari, *Molecular Revolution in Brazil*, 1, p102.
[166] Guattari, *Molecular Revolution in Brazil*, 1, p103.
[167] Guattari, *Molecular Revolution in Brazil*, 1, p35.
[168] Guattari, *Molecular Revolution in Brazil*, 1, p35.

journey to show us the extensive reach of the *capitalistic* system in these terms and beyond, right into the recesses of our minds.

In her opening statement, Rolnik refutes the use of the term '*ideology*',[169] preferring to speak in terms of '*subjectiviation*' or the '*production of subjectivity*'.[170] The term 'ideology' is a type of superstructure impinging on the true expression of subjects' desires. A ready-made prison that hems in a flourishing person. Rolnik uses the metaphor of being fed mother's milk to an infant as similar to the 'injection' of ideology into subjectivity.[171] She speaks of the superstructure that composes our understanding of what it means to become individualised, being injected and being formed in the notion of an individual as opposed to the processual development of our personhood through desirous pathways that we might call personological. In particular, she refers to superstructure models that form us, such as 'Oedipuses, and triangulations',[172] referring to Freud and the institutions of psychiatry and psychology that disseminate these types of signification, creating ready-made subjectivities for our modern-day consumptions. It is as if the Oedipal relations with other mothers and fathers are the only way to relate. Rolnik is critical of how readily this superstructural logic is used in professions of the psyche (*psy sciences*) and extended to all models or ideologies of everyday social life. She even finds the use of such psychoanalytic superstructures influencing and impinging on her everyday work as a practising therapist and committed Marxist.

Rolnik and Guattari suggest that for so long, we have taken for granted the subjectivities of the 'other', those we call minorities, who incidentally together make up the majority of the world population.[173] Somehow, because they do not fit neatly into the production and consumption assembly line, they are portrayed as purveyors of chaos and a threat to society, and are critical of the dominant subjectivity. The capitalist produced individuals (subjectivities), the invention of the capitalistic mode of semiotic genesis is the yardstick by which all others can be measured, and those who do not meet this yardstick are punished or made to feel shame (culpabilisation or a target for reterritorialisation). This is problematic for Rolnik, because those who, like the marginalised '"[a]rchaic" societies'[174] or 'people in psychiatric hospitals […] unable (or unwilling) to enter the dominant systems of signification, have a perception of the world utterly different from that is

[169] Guattari, *Molecular Revolution in Brazil*, 1, p35.
[170] Guattari, *Molecular Revolution in Brazil*, 1, p35.
[171] Guattari, *Molecular Revolution in Brazil*, 1, p35.
[172] Guattari, *Molecular Revolution in Brazil*, 1, p35.
[173] Guattari, *Molecular Revolution in Brazil*, 1, p37.
[174] Guattari, *Molecular Revolution in Brazil*, 1, p37.

customary schemes.'[175] This doesn't mean they are chaotic. Rather, they have different subjectivities— different viewpoints.

Using the Marxist concept of 'infrastructure of production',[176] Rolnik suggests that machinic (the autonomic desirous drive to connect systems together) superstructures, far and wide, control relations mediated by semiotics, becoming intrinsic clogs of IWCs, and have spread their machinations across the social field. She says that '[t]*he production of subjectivity is the raw material for any and all production*',[177] more important than 'the production of petroleum and energy'.[178] IWC encompasses all processes, including scientific, biological, telecommunications, computer, robotics, and media-related fields. This mode of production subjugates the individual's unconscious and directs it toward material and semiotic creations of standardisation. They are not simply concerned with the domain of ideology and representation 'but also a modelization behavior, sensibility, perception, memory, social relations, sexual relations, imaginary phantoms, etc.'[179] The 'structural equivalence and translatability' of this ever-shifting super-superstructural foundation harnesses the collective economy of desire. IWC target the very roots, the very genesis of the processual systems that give rise to the notion of being the singular ('singularity'[180]), which is the central notion of their ideals on subjectivity, and misshapen it to create markets for consumption and production.

The psychoanalysts suggest that Marxist infrastructure production is the system that foregrounds both colonisation and capitalistic development in the Third World.[181] Capitalistic subjectivity adopts a slash-and-burn approach in those so-called cultures and systems of social relations that diverge from the normative, idealised notion found in IWC. The capitalistic way insists that those cultures must be subjugated a priori to the installation of 'economic expansion'.[182] We might consider how America intervenes in countries to liberate them and introduce neoliberal democracy in Africa, South America, the Middle East, and Asia—the travesty of the Korean War, Iran and Iraq, to mention but a few. This capitalistic expansionism is the cornerstone of United States incursions into the Third World, says Rolnik. '[W]ithout this work [manipulation] on all the milieus involving economic, commercial, and industrial semiotization, local social realities cannot be controlled',[183] suggest Rolnik and Guattari.

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[175] Guattari, *Molecular Revolution in Brazil*, 1, p38.
[176] Guattari, *Molecular Revolution in Brazil*, 1, p39.
[177] Guattari, *Molecular Revolution in Brazil*, 1, p38.
[178] Guattari, *Molecular Revolution in Brazil*, 1, p36.
[179] Guattari, *Molecular Revolution in Brazil*, 1, p39.
[180] Guattari, *Molecular Revolution in Brazil*, 1, p39.
[181] Guattari, *Molecular Revolution in Brazil*, 1, p39.
[182] Guattari, *Molecular Revolution in Brazil*, 1, p39.
[183] Guattari, *Molecular Revolution in Brazil*, 1, p39.

Revolutions and 'problematics of micropolitics' seek to express affective changes at the macropolitical level for IWC, which is a key message for Rolnik and Guattari.[184] What is interesting is how this comes about. For Rolnik, it is about changes at the local level (personological), the very grassroots expression of unfamiliar and often unheard notions of singular experiences that relate one to the other, whatever that other may be. It's not all about changing the semiotics, creating a new structure of representation, or inserting new levels of reference or language, but rather about allowing the process of 'singularity' to beget latent subjectivities to emerge 'because they are the very productive roots of subjectivity in its plurality.'[185] Rolnik advocates considering all micropolitical modes of expression in the interchange between the macropolitical structural formations on multiple fronts. This passionate belief is how Rolnik and Guattari set out to tour Brazil in 1982. Rolnik refers to the example of Iran, Poland and Afghanistan to highlight that these are not mere ideological clashes between civilisations but 'a confrontation with how subjectivity is now manufactured on a world scale'[186].

This brings the politics of desire and subjectivity into focus and foregrounds the examination of subjectivity through a tempered arrangement of Marxism with the *psy sciences*. Rolnik and Guattari repeatedly borrow and critique various fields from history, sociology, anthropology, and linguistics as they play out various concepts and their impacts on subjectivity. A strong sensibility defines this book, and it accounts for the logic by which Rolnik and Guattari envision us developing into more interrelated and aware agencies with a propensity to adapt to and develop in various situations.

> The guarantee of processual micropolitics can only – and should only – be found at each step, on the basis of the assemblages that constitute it, and through the invention of modes of reference and modes of praxis. This invention makes it possible to elucidate a field of subjectivation, and at the same time, to intervene effectively in that field, both within it and also in its relations with the outside. For the social professional, everything depends on the ability to work with assemblages of enunciation that assume their responsibility on the micropolitical plane.[187]

Rolnik and Guattari argue that assemblages of enunciation—the concrete arrangements of signs, bodies, expressions, and power relations—the utterances that emerge from these contextual relations—must develop their own modes of understanding and action rather than following predetermined formulas or models. For micropolitics to be truly transformative, it must constantly reinvent itself through engagement with specific situations, allowing social workers and activists to

[184] Guattari, *Molecular Revolution in Brazil*, 1, p39.
[185] Guattari, *Molecular Revolution in Brazil*, 1, p39.
[186] Guattari, *Molecular Revolution in Brazil*, 1, p40.
[187] Guattari, *Molecular Revolution in Brazil*, 1, p41-42.

intervene effectively by working with actual assemblages rather than imposing external frameworks. Although Rolnik and Guattari assure us through this book that there are no hard-and-fast rules to follow, this is a good principle on which to build a micropolitical revolution.

Molecular revolutions: daring to singularize

Rolnik and Guattari propose 'molecular revolution'[188] as a process for the resistance of subjective submission, suggesting it might be necessary to express 'original, singular modes of subjectivation'.[189] The micropolitical is the singularizing service of reappropriating subjectivity through local relations that circumscribe it. According to Rolnik, '[t]he function of autonomization' comes about through this process, setting into motion the reconstitution of power relations and the reconfiguration of alliances within one's subjectivity.[190] Carrying out its subjective mode of work initiates the genesis of its semiotic structures, creating its modes of representation, inserting its functioning cartographies of situatedness, which Rolnik calls 'experience of a subject-group'.[191] That is the group that is in charge of its own destiny. Rolnik and Guattari explain it in this way:

> *The idea of molecular revolution concerns every level synchronically: infrapersonal (at work in dreaming, creation, etc.), personal (in relations of self-domination, what psychoanalysts call the superego), and interpersonal (in the invention of new forms of sociability in domestic, romantic, and professional life, and in relations with neighbors and school).*[192]

These ways of relating and referencing one's subjectivity are expressions of the singular subjectivity or the singularized desires that operate as an assemblage and a vector of construction and resistance, simultaneously. In that case, Rolnik suggests subjectivity must be focused on questioning the dominant forces of embodied experience and acting against the flood of internalised forces that are the derivatives of IWC in the 'control grid [quadrillage] of power'.[193] IWC influences extend beyond the bounds of the markets and media, shaping and defining those very institutions that shape and define us. Rolnik specifies that '[a] molecular revolution consists in producing conditions not only for collective life but also for the embodiment of life for oneself, both materially and subjectively.'[194] The conditions referred to here, as she describes, are those that organise life differently, among minorities, the marginalised, and the dispossessed or indeed 'among creative

[188] Guattari, *Molecular Revolution in Brazil*, 1, p61.
[189] Guattari, *Molecular Revolution in Brazil*, 1, p61.
[190] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[191] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[192] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[193] Guattari, *Molecular Revolution in Brazil*, 1, p31.
[194] Guattari, *Molecular Revolution in Brazil*, 1, p63.

workers eager to free themselves from standardising systems in their field'.[195] The process that supports these environments requires constructing new logic without falling into fascism, blind alleys, or dead ends, enabling new territories and assemblages where people feel at ease and experience the 'warmth of relations'.[196]

Guattari explores how subjectivity might escape pre-existing 'images'[197] through what he calls a 'vector of molecular revolution'[198] that can achieve 'functions of autonomy'.[199] He points to how artists and social movements can express singularized experiences that reject capitalistic subjectivity, defining the molecular revolution as 'the awakening of this notion of desire, both on a microscopic level and on a social scale'.[200] However, he warns that molecular revolutions can slip into 'microfascism' when operating on the 'molar plane' of dominant representations.[201] As Rolnik notes, '[t]*he fear of losing houses and objects in nothing in comparison with the terror of losing oneself*'.[202] The solution, according to Guattari, lies in a revolution of 'establishing devices that articulate dissident modes of expression to the dominant modes of expression',[203] particularly in contexts like Brazil, where social movements are actively challenging existing power structures.

Revolution

To understand how Rolnik and Guattari envision their molecular revolution manifesting in a revolution in Brazil, we must comprehend their view of subjectivity as the catalyst for change. Guattari takes great pains to define the term 'revolution' at a molecular level as one that has a processual character '*that brings about mutations in the unconscious social field, at a level beyond discourse. We could call it a process of existential singularization*'.[204] In simple terms, Guattari redefines 'revolution' by zooming in to examine change at a microscopic or 'molecular' level. Rather than focusing on big structural changes like traditional political revolutions, he's interested in subtle shifts that happen beneath the surface—in how people think, feel and relate to each other at an unconscious level. These changes aren't necessarily visible or expressed through language but rather occur through transformations in how people experience their own existence in unique and singular

[195] Guattari, *Molecular Revolution in Brazil*, 1, p67.
[196] Guattari, *Molecular Revolution in Brazil*, 1, p63.
[197] Guattari, *Molecular Revolution in Brazil*, 1, p72.
[198] Guattari, *Molecular Revolution in Brazil*, 1, p73.
[199] Guattari, *Molecular Revolution in Brazil*, 1, p74.
[200] Guattari, *Molecular Revolution in Brazil*, 1, p76.
[201] Guattari, *Molecular Revolution in Brazil*, 1, p86.
[202] Guattari, *Molecular Revolution in Brazil*, 1, p86.
[203] Guattari, *Molecular Revolution in Brazil*, 1, p90.
[204] Guattari, *Molecular Revolution in Brazil*, 1, p259.

ways. To use his terminology from the quote above, it's a 'processual' revolution—meaning it unfolds gradually through ongoing processes rather than sudden ruptures—leading to 'existential singularization', where people develop distinctive new ways of existing that break from standardised social norms. Think of it this way: instead of a dramatic overthrow of a government (a macro-revolution), Guattari is examining tiny mutations in society's DNA—small but profound changes in how individuals and groups perceive reality and construct meaning. These molecular changes eventually accumulate to create new ways of being that can't be simply explained through conventional political discourse or ideology.

For Guattari, all types of revolutions are processual and bring about a change that is transformative, 'unpredictable'[205], and 'cannot be permanent'.[206] The molecular character of repetition in the processes of mutation gives rise to what he calls 'microprocesses in a nascent state',[207] which must be articulated through culture, people, and 'practices of change in the way of life with their creative potential'.[208] Guattari suggests that there are no guarantees that these revolutions will always succeed, as they may fail; his concept of revolution is not a romantic ideal.

Brazil

Guattari sums up his thirty-day whirlwind trip around Brazil during this tour in 1982 with Rolnik as a type of 'exploratory machine that tries to penetrate different areas'.[209] As with any 'assemblage of enunciation,'[210] explored by Guattari, its purpose is to invigorate and catalyse the molecules of agitation, to map and understand 'cartographies'[211] of power in their relations and their 'microevents.'[212] Throughout their trip, Guattari says they attempted to integrate the concepts of psychoanalysis, specifically the comprehensive examination of processes that lead to 'class struggle.'[213] Guattari notes that their conversation gravitated around the concept of 'lack' for a significant amount of time.[214] He did this because he wanted to show that their concepts exceed the Lacanist and Marxist treatments and that of the '*politics introduced by the division between guaranteed* [elites] *and nonguaranteed* [precarious working class]*, the politics of culpabilization and*

[205] Guattari, *Molecular Revolution in Brazil*, 1, p259.
[206] Guattari, *Molecular Revolution in Brazil*, 1, p259.
[207] Guattari, *Molecular Revolution in Brazil*, 1, p260.
[208] Guattari, *Molecular Revolution in Brazil*, 1, 261.
[209] Guattari, *Molecular Revolution in Brazil*, 1, p427.
[210] Guattari, *Molecular Revolution in Brazil*, 1, p427.
[211] Guattari, *Molecular Revolution in Brazil*, 1, p427.
[212] Guattari, *Molecular Revolution in Brazil*, 1, 427.
[213] Guattari, *Molecular Revolution in Brazil*, 1, p428.
[214] Guattari, *Molecular Revolution in Brazil*, 1, p428.

castration that is peculiar to capitalistic subjectivity.'[215] Guattari states that his inferences are directly linked to the means of production and the schizes the systems produce in terms of their attribution, distribution, and stratifying nature. He suggests that the markets permeate the concept of *lack* as their intrinsic mode in constructing the apparatuses involved in producing this particular type of dominating subjectivity. For Guattari, this is not inherent in humanity but a constructed function of capitalistic subjectivity, to be more precise.

Another noteworthy issue for Guattari is that the conversations he recalls framed the struggles as the 'social struggle, [and] class struggle[…] in terms of a dualistic logic',[216] which for him seemed all too inescapable. He says that this is stultifying and that all contexts of issues for analysis have a '*micropolitical and analytical dimension*',[217] wanting to urge us always to consider, in our scrutiny, thereby averting the impasse of oppositional postures such as the duality of class struggle (an inflected critique of Marx). In effect, nothing for Guattari is ever settled; nothing is ever sedimenting even on analytical terms because everything that is regarded as '*singularity*'[218] is part of the system that is 'precarious, provisional contracts, subject to revision.'[219] Just as we are destined to die, so are our experiments destined to fail. The moment we can come to accept this is when we accept our 'finiteness,'[220] claims Guattari. He assures Suely that this is the continuous process to which the 'process of singularization'[221] must ascribe. It is the nature of its 'processual character of the undertaking'[222] for Guattari; however, this eternal character provokes the lines of creativity and experimentation, 'engendering of new universes, it's engendering of rhizomes of all kinds.'[223]

Rolnik was grateful for Guattari's contribution and interjections into the national discourse during a time when Brazilian history witnessed the emergence of 'the "crisis" into which capitalistic development and its deterritorializing force has plunged'[224] Brazil, and tried to displace the previous totalising regime of colonialisation and dictatorship. Rolnik draws attention to Guattari's talents as one who can detect the changing vital and temporal pulses of discourses of major political currents of change worldwide, citing her experiences of his previous activism, which dates back to Paris in 1968, as well as the more recent changes in the industrialisation of Japanese culture. Rolnik says

[215] Guattari, *Molecular Revolution in Brazil*, 1, p428.
[216] Guattari, *Molecular Revolution in Brazil*, 1, p428.
[217] Guattari, *Molecular Revolution in Brazil*, 1, p429.
[218] Guattari, *Molecular Revolution in Brazil*, 1, p429.
[219] Guattari, *Molecular Revolution in Brazil*, 1, p429.
[220] Guattari, *Molecular Revolution in Brazil*, 1, p430.
[221] Guattari, *Molecular Revolution in Brazil*, 1, p430.
[222] Guattari, *Molecular Revolution in Brazil*, 1, p430.
[223] Guattari, *Molecular Revolution in Brazil*, 1, p430.
[224] Guattari, *Molecular Revolution in Brazil*, 1, p430.

with gratitude, 'I would even say that this is your art: the art of cartography of desire, the art of the analyst, of the schizoanalyst.'[225]

Guattari's journey to Brazil, according to himself

Guattari's fascination with 'Latin America'[226] is borne from his desire concerning the nascent problematic and those he believes are 'being conjugated'[227] in the time and space of his time during his travels through Brazil. He considers it an awakening into the ascent out of poverty and into the hands of American-style cultural projects, which he sees as the extension and overreach of the tentacles of IWC, a rife battleground for the basis where one can ward off Latin cultural appropriation through this system of production of subjectivity.[228] The relationship between subjectivity and politics, as articulated by Guattari, concerns the 'collective assemblage of enunciation'[229] which expresses what he defines as the 'formation of the unconscious'.[230] Guattari's references throughout the book to the collective unconscious rising to the forefront of political actions are the basis of the molecular revolutions. Guattari's focus on Latin America, and specifically Brazil, is particularly significant as it represents what he sees as a unique convergence of multiple social, political and economic forces. As he states, 'Latin America is Africa, Asia, and Europe at the same time'[231]—this intersection makes it an ideal site for observing the dynamics between emerging forms of collective consciousness and the expanding influence of IWC.

His concept of collective assemblage of enunciation becomes especially relevant in this context, as it describes how collective forms of expression and resistance emerge in response to capitalistic forces. Brazil, at this historical moment, exemplified both the threats posed by capitalist subjectivation and the potential for alternative forms of collective consciousness to emerge. This tension between capitalistic appropriation and collective resistance makes Latin America a crucial case study for understanding how molecular revolutions might manifest in practice. Furthermore, Guattari's interest in Latin America reflects his broader theoretical concern with how collective unconscious formations can emerge into political action, particularly in contexts where traditional Western models of development and subjectivity meet local forms of resistance and cultural

[225] Guattari, *Molecular Revolution in Brazil*, 1, p431.
[226] Guattari, *Molecular Revolution in Brazil*, 1, p437.
[227] Guattari, *Molecular Revolution in Brazil*, 1, p437.
[228] Guattari, *Molecular Revolution in Brazil*, 1, p437.
[229] Guattari, *Molecular Revolution in Brazil*, 1, p438.
[230] Guattari, *Molecular Revolution in Brazil*, 1, p437.
[231] Guattari, *Molecular Revolution in Brazil*, 1, p437.

expression. This adds valuable context to the existing explanation about Guattari's engagement with Latin America and his conceptualisation of molecular revolution.

Guattari views Brazil, a country of nearly one hundred million people, as a grand-scale experiment. He believes these revolutions are gripped by the articulations of 'precisely […] what seems to me to be a general problem of [how] the world crisis is apprehended, semiotized, and mapped in the various contexts.'[232] He discusses the work of Jack Lang[233] and his UNESCO project which aimed to combat the capitalistic semiotization of culture during the 1980s, leading to his 'global "crusade" to combat cultural imports from the United States'.[234] This is important to Guattari because it is the conjugation of the stratifying, wholesale liquidation of processes that are part of the process of emergence in the collective roots of subjective productions. These advances articulate the processes that potentially lead to the singularization of assemblages found in minorities and the marginalised, which Guattari cares so much about in bringing about molecular revolutions.[235]

In the same way, Guattari dislikes formal communication processes, those of 'academic talk'[236]. He feels that these processes are exploitative and responsible for the loss of 'the resources of information and communication',[237] which are rich in their existence as 'nonwritten elements' found in speech. This is especially important in oral cultures. He even dislikes the image of his 'Professorial' quasi-academic portrayal. This is the reason why he set about his tour of Brazil, having negotiated with Suely to limit the number of formal lectures he would give, instead concentrating on meetings and interviews that would bring 'intense political, cultural, and social agitation.'[238] So, capturing his ideas in a thesis (like this one) may be somewhat provocative for him. He focused his desires on those he felt would be motivated in grassroots projects concerning minorities and community projects, not cultural, institutional programs and educational, governmental strategies:[239] in line with his free radio experiences and his 'alternative experiments in psychiatry'[240] during the 1960s. Guattari's work was particularly focused on seeking to be an interlocutor whose agitation functioned

[232] Guattari, *Molecular Revolution in Brazil*, 1, p438.
[233] Guattari, *Molecular Revolution in Brazil*, 1, p437.
[234] Richard F. Kuisel, "Anti-Americanism in Retreat: Jack Lang, Cultural Imperialism, and the Anti-Anti-Americans," (Princeton: Princeton University Press, 2011). Jack Lang was French Ministry of Culture from 1981 to 1986 and again from 1988 to 1993 in the Giscard d'Estaing government. He railed agains American Cultural imperilaism
[235] Guattari, *Molecular Revolution in Brazil*, 1, p437-38.
[236] Guattari, *Molecular Revolution in Brazil*, 1, p438.
[237] Guattari, *Molecular Revolution in Brazil*, 1, p438.
[238] Guattari, *Molecular Revolution in Brazil*, 1, p440.
[239] Guattari, *Molecular Revolution in Brazil*, 1, p440.
[240] Guattari, *Molecular Revolution in Brazil*, 1, p440.

as a kind of 'catalyst'[241] in 'the fields of effectuation'[242] outside or within the territories of other 'semiotic registers'[243] that were holding the attention of the people involved in the Brazilian struggle. After all, that is the whole point of a molecular revolution.

In the summation notes of his reflection, Guattari claims that the preponderance of capitalistic flows sweeping Brazil at the time, during his tour with Rolnik, conjured for him a great experiment in the potentiality of 'capitalist mutation', one that is on the scale of the United States. It is for this reason that this project holds great importance for him. For Guattari, this was an experiment in warding off the forebodingly inevitable doom of subjectivity into the malaise of 'capitalistic unconscious'.[244] Guattari doesn't see countries; he sees 'world cities' like Fernand Braudel, whose philosophies of history and insights he has referenced often throughout this book. Like Braudel, he prefers nodes and connections instead of territorial borders. These nodes, like cities, are the places that can be generators of 'subjectivity'.[245] A kind of engine room of self-modifying, always generating, as he describes in his own words, a 'process that is created and later dies like the stars.'[246] Guattari stresses that this project, referring to the molecular revolutions of subjectivity, the micropolitical battles over the body, is all about desiring machines, be they abstract, collective, singular, 'concrete, and affective, and social'.[247]

It is challenging to summarise Guattari's attitude, as evident in his responses to his interlocutors during his trip to Brazil. However, one thing is certain: he often appears like many different people, exhibiting vast attitudinal shifts. At times, he refers to the very nature of people as wretched,[248] and his attitude reflects a certain disdain, yet in the preface, he describes himself as 'optimistic'.[249] But suppose we accept his activism as a type of hyper-energetic and optimistic molecular-catalytic drive for change. In that case, this quote is probably the best summation of this approach to the book *Molecular Revolution in Brazil*.

> I think that we're in a period of productivity, proliferation, creation, utterly fabulous revolutions from the viewpoint of the emergence of a people. That's molecular revolution: it isn't a slogan or a

[241] Guattari, *Molecular Revolution in Brazil*, 1, p441.
[242] Guattari, *Molecular Revolution in Brazil*, 1, p441.
[243] Guattari, *Molecular Revolution in Brazil*, 1, p441.
[244] Guattari, *Molecular Revolution in Brazil*, 1, p452.
[245] Guattari, *Molecular Revolution in Brazil*, 1, p453.
[246] Guattari, *Molecular Revolution in Brazil*, 1, p453.
[247] Guattari, *Molecular Revolution in Brazil*, 1, p455.
[248] Guattari, *Molecular Revolution in Brazil*, 1, p457.
[249] Guattari, *Molecular Revolution in Brazil*, 1, p9.

program, its something that I feel, that I live, in meetings, in institutions, in affects, and also though some reflections.[250]

The new smoothness

The struggles of the molecular revolution, through subjectivity, daring to singularize and develop a profound sense of self while creating an ethical, self-developed social system of relations, bring about a change that Rolnik and Guattari call the new smoothness. Achieving this modal social and ethical change requires us to understand a few of Rolnik's and Guattari's critiques (such as their critique of identity) and the way the molecular works through desire to bring about such a profound change.

In search of identity

In today's world, subjectivity and identity seem to be inextricably linked. Guattari is critical of the constituent structures that form the concept of identity and the inability of these concepts to grasp the subjectivation (or singularizing) process of some minorities. This is a barrier that needs to be overcome before we can reach the new smoothness. Guattari believes that current capitalistic systems not only fail to create a hyperstatic or intransigent subjectivity through identity, but rather, they act as vehicles of 'disorder and entropy'.[251] They fail and subordinate subjects to neat structures that inadequately describe their identities. These systems include the pervasive notions of 'psychic agencies, [and] the way of perceiving the world'[252]—the way we lack the empathy to see the mentally ill and our inability to see their perspectives of the world. The embodying process of singularization and its inscribing pre-personal semiotisation of the unconscious is subject to the reductionist interpretive methods of Freudian discourses on images and Lacan's matheme of 'object "a"',[253] which reincorporate as systems of representations that Guattari abhors. Instead, Guattari went early to a more open set of object relations. He refers to Winnicott's 'transitional objects' as an example, averting the modal fixation found in other object theories, which are so dependent on fixed idealisation that they cannot do what transitional objects do, which is to consider an external

[250] Guattari, *Molecular Revolution in Brazil*, 1, p457.
[251] Guattari, *Molecular Revolution in Brazil*, 1, p91.
[252] Guattari, *Molecular Revolution in Brazil*, 1, p91.
[253] Guattari, *Molecular Revolution in Brazil*, 1, p92.

system that gives way to other possibilities.[254] Identity for Guattari is a system of economies of objects that are the causational inputs that orient identity to implode '*inwards*'[255] or explode '*outwards*'.[256] Instead, a 'twofold' decentralisation is required to characterise the processes that assemble the notion of identity. The 'infra-personal (the molecular dimension)' and the 'concatenations of social, economic, and machinic relations'.[257]

Micropolitics: molar and molecular

The new smoothness comes in the wake of a molecular revolution. Let us examine the molecular aspect a little more closely in the context of the micropolitics of subjectivity. In a chapter titled 'Micropolitics: Molar and the Molecular', the terms molar and molecular are loosely borrowed from chemistry, transfigured by Guattarian translations from his early studies in pharmacy[258] into his processual-philosophical-analytical insight to express the types of micropolitical systems of subjectivity. These syllogisms and their idiosyncratic uses are extended and drawn upon for their mobility in the field of social relations and the formation of the polycentric notion of subjectivity. This is the basis on which Guattari posits all his ideas on subjectivity. This type of mobilisation of social relations will cut across all the delineating boundaries that isolate individuals in modern societies, bringing meaning and understanding back to the subject.

Think of the molar as the standardised, measurable way we describe chemical substances—like how we measure atoms using fixed units and weights. It's the regulated, institutional system that helps us understand chemistry in a structured way. The molecular, on the other hand, represents the raw potential and fragments that exist before they're standardised—like individual atoms with their electron charges, which can combine in countless ways depending on their environment. These molecular interactions create the foundations for life itself, whether in DNA or other chemical compounds. While capitalism attempts to control and commodify these molecular processes through molar regulations (as in industrial chemical production), it can't fully capture the natural wonder and creativity that occur at the molecular level. That's where art comes in—helping us see the beauty in these molecular transformations that make life possible. So, in simple terms, molar = structured/regulated system, molecular = creative potential and natural interactions. Both are important, but they work in different ways.

[254] Guattari, *Molecular Revolution in Brazil*, 1, p92.
[255] Guattari, *Molecular Revolution in Brazil*, 1, p92.
[256] Guattari, *Molecular Revolution in Brazil*, 1, p92.
[257] Guattari, *Molecular Revolution in Brazil*, 1, p93.
[258] Guattari, *Molecular Revolution in Brazil*, 1, p179.

The way we understand molecular creativity in chemistry can help us think differently about how the mind works. Instead of following Freud's or Lacan's structured models of the psyche (the molar approach), Guattari suggests we look at the flowing, changing processes of the unconscious (the molecular approach). For Guattari, this isn't just making comparisons—it's about understanding how desire and subjectivity actually emerge from these molecular processes in our unconscious.[259] It's not about representing or symbolising these processes but about tracing how they actually flow and work. This has a great deal of relevance for subjectivity because it becomes foundational to how we construct ourselves and learn to relate to the creation of others (how others are perceived), especially in helping us appreciate difference and otherness.

In other words, Guattari wants us to focus on the dynamic, molecular nature of our unconscious rather than trying to fit it into rigid structures or systems: that is clear from his opening statement that '[t]*he micropolitical question —that is, the analysis of formations of desire in the social field*'.[260] Guattari sees it as a pivot to the field of social relations. He employs an ethical, processual approach to searching for accounts of rhizomic courses that flow between the molar and molecular formations of desire. Guattari maintains that a way of understanding this is 'the way in which the level of broader social differences (which I call "molar") intersects with the level that I call "molecular".'[261] The exemplary processes of micropolitical transformation of the molecular should aim to uncover human subjectivity through these processes of charged reactions that emerge from desire, as suggested here by Guattari. Desire is the multifaceted binding force for the formulation and reformulation of subjectivity. This is to be carried out with precise accuracy, taking into account contingent levels of understanding of the unconscious beginnings, which account for its molecular variance, representing its creative revolution. It is an interpretation and an extension of Guattari's statement: '*social struggles are molar and molecular at the same time.*'[262]

The molar and molecular processes of exchange can help guide the mobility of our subjective incongruities in the face of diverse states of subject formation, thus permitting us to circumvent impasses and expand our experiences and sensibilities. For Guattari to think of one without the other (molar without the molecular) is not possible, as he intimates, '[t]his opposition between molar and molecular may be a trap […] [t]he molecular, as a process, can originate in the macro [molar].'[263] The process under which subjective formulation is articulated through 'influences', 'associations', 'dissociations', 'exchanges' and at the intersection of processual becoming. Guattari

[259] Guattari, *Molecular Revolution in Brazil*, 1, p190.
[260] Guattari, *Molecular Revolution in Brazil*, 1, p179.
[261] Guattari, *Molecular Revolution in Brazil*, 1, p179.
[262] Guattari, *Molecular Revolution in Brazil*, 1, p179.
[263] Guattari, *Molecular Revolution in Brazil*, 1, p180.

views our bodies and minds as being immersed in a sea of forces that shape who we become. Just as in chemistry, where structured compounds (molar) can always be broken down into their smaller parts (molecular), he sees how rigid social structures can be broken down into more fluid, changing elements. Think of it like this: in chemistry, molecules can recombine in different ways depending on their environment. Similarly, Guattari suggests that people have the potential to change and combine in new ways. However, capitalism acts like a chemical reagent - it tries to force these fluid, molecular expressions into fixed, structured (molar) forms, like how it shapes the ideal of the individual.

So, what Guattari and Rolnik are saying is that while we have the potential for many different ways of being, capitalism pushes us towards more rigid, idealised, and standardised forms of existence. Guattari's molar and molecular are intended not to be paired in dialectic discussions or oppositional entanglement but instead to inform one another, just as 'social struggles are molar and molecular at the same time'.[264] Just like in chemistry, our desires and unconscious mind can shift back and forth, like a chemical reaction. We can move between fixed states (molar) and fluid states (molecular), depending on our environment. This creates what Guattari, drawing from chemistry, calls a balance between stability and change (metasability).[265] When we talk about becoming ourselves, we're always moving between these molecular desires and molar structures. Similar to chemistry, we must consider all possible combinations and transformations that can occur between these states. Guattari sees the 'molar' in society as the way capitalism tries to shape and control us. It's like a pre-made template for who we're supposed to be—think of how Freud and Lacan describe how we become individuals or how society tells us who 'I' am supposed to be. As Guattari says, it creates 'the same kind of impossibility of escaping from this pseudo-personological siege'.[266]

What Guattari calls the '*micropolitical approach*'[267] is where different modes of understanding ourselves intersect. Guattari suggests that institutions like churches, universities and media act as 'collective facilities'—they try to channel our real desires into forms that suit capitalism, creating what Guattari describes as 'remote control'[268]of our personalities. Through work and consumption, we become alienated from our true desires, leading to what Guattari suggest is a 'subjective

[264] Guattari, *Molecular Revolution in Brazil*, 1, p179.
[265] Guattari follows the relational lingustic terminology found in chemistry to the molar and the molecular and in the footnotes to this Chapter we find this terms is a reference to “Ilya Prigogines’ (awarded the 1979 Nobel Prize for Chemistry) and Isabelle Stengers” work on fluctuations and equilabrium. Guattari, *Molecular Revolution in Brazil*, 1, p489.
[266] Guattari, *Molecular Revolution in Brazil*, 1, p181.
[267] Guattari, *Molecular Revolution in Brazil*, 1, p183.
[268] Guattari, *Molecular Revolution in Brazil*, 1, p181.

boredom'[269] or malaise. To break free, we need 'micropolitical analysis'[270] to examine '*the theatre of affects*'[271] , looking at how these big systems interact with our personal desires at the smallest level. For democracy to work, Guattari says we need to let these molecular, personal forces flow freely to create 'new attitudes, new sensibilities, new praxis, which prevent the return to old structure'. [272] This means avoiding what he calls 'factors of culpabilization'[273]—feelings of guilt that make us conform to social norms and allow desire to bring into force new connections of thought and habit, new alliances and relations.

Love, territories of desire, and a new smoothness

Extending his concepts of desire, Guattari turns to territories of love to show how differentiated desires are. For Guattari, love has the potential to lead to dead-end territories.[274] The love we experience, he says, especially that of what he so splendidly calls the 'conjugal economy'[275], referring to the stereotypical models of domesticity, 'neutralizes each and every possibility of richness (including sexual desire), every opening.'[276] Guattari prefaces this by saying, 'it has nothing to do with the idea of "anything goes"', just that it simply limits the territories of extension for connectivity, for '"freeing oneself," with "enjoying the body"'.[277] Even drugs somehow work in establishing extensive territories of subjectivity, and here he refers to LSD and the experimentation of the poet Henri Michaux[278]. He admits that opening up the process that leads to creativity and multivariant mutations is not as common as some would like us to believe. As always, like any process, there are no guarantees, as 'the economy of desire can also lead to the phenomena of catastrophe, to a black hole.'[279]

Guattari suggests that our minds have been shaped by the cartographies of power and control derived from institutional, cultural, political, and even conjugal units, which serve as examples of accepted norms, our discourse, and so on. However, it is not surprising to suggest that our bodies are also subject to these systems through the delimitations of marriage. Therefore, Guattari demonstrates how profoundly ingrained and profound such matters are in shaping subjectivity. He

[269] Guattari, *Molecular Revolution in Brazil*, 1, p182.
[270] Guattari, *Molecular Revolution in Brazil*, 1, p185.
[271] Guattari, *Molecular Revolution in Brazil*, 1, p189.
[272] Guattari, *Molecular Revolution in Brazil*, 1, p190.
[273] Guattari, *Molecular Revolution in Brazil*, 1, p190.
[274] Guattari, *Molecular Revolution in Brazil*, 1, p404.
[275] Guattari, *Molecular Revolution in Brazil*, 1, p404.
[276] Guattari, *Molecular Revolution in Brazil*, 1, p404.
[277] Guattari, *Molecular Revolution in Brazil*, 1, p404.
[278] Guattari, *Molecular Revolution in Brazil*, 1, p405.
[279] Guattari, *Molecular Revolution in Brazil*, 1, p405.

imagines that we shape our bodies and mannerisms to conform to the language, cultures, and institutions that are part of the codified 'quantitative global impulses.'[280] Guattari speaks of how the notion of the body has been transformed through history from the marking of the '*socius* by tattoos, by initiations, and so on'[281], that is, part of social orders, ingrained in the fabric of what he terms 'social body'[282] seen in the 'archaiac body'[283], into the totalised, modelised, individuated units of today. For Guattari, these individuated, isolated islands sit in oceans subject to the political and institutional currents of capitalistic order within an underlying grid of control that he refers to recursively. Guattari gives us an example of how our perspectives on our bodies have also changed to become redundant with respect to the dominant modes of subjectivity[284], pointing out that '[t]he archaic body[..] is never [thought of as] a naked body, it is always a subset of the social body'.[285] Fashion, identity, trends, the way we speak, culture, and the technologies we surround ourselves with are all apparatuses that precede the production of subjectivity. Guattari specifies that, indeed, these are systems that are not biological but rather a 'sensibility, the relations with the world'[286]and as such, he faults Voltaire for suggesting the notion that we are responsible for 'cultivating one's [sic] garden'[287]. Guattari posits that

> [i]n 'developed' industrial societies, things are represented as if we had a body, but it's not as obvious as that. I think that they attribute a body to us, they produce a body for us, a body capable of developing in a social space, a productive space, for which we are responsible.[288]

In response to the question of 'sexual liberalization as a normalization of sexuality?'[289] Guattari is very clear. This process of capture is part of the apparatus of capture that inculcates any form of desire, stratifying it and capitalising upon it to prevent excess 'reserves of capacity to express revolt'[290]. He sees this as an insurance strategy developed by capitalism to divest from personal desire into the cauldron of capitalistic desire, which brings us back to the concept of labour: '*Now the machine of desiring is a machine of working.*'[291]

[280] Guattari, *Molecular Revolution in Brazil*, 1, p407.
[281] Guattari, *Molecular Revolution in Brazil*, 1, p409.
[282] Guattari, *Molecular Revolution in Brazil*, 1, p409.
[283] Guattari, *Molecular Revolution in Brazil*, 1, p409.
[284] Guattari, *Molecular Revolution in Brazil*, 1, p410.
[285] Guattari, *Molecular Revolution in Brazil*, 1, p409.
[286] Guattari, *Molecular Revolution in Brazil*, 1, p409.
[287] Guattari, *Molecular Revolution in Brazil*, 1, p409.
[288] Guattari, *Molecular Revolution in Brazil*, 1, p409.
[289] Guattari, *Molecular Revolution in Brazil*, 1, p412.
[290] Guattari, *Molecular Revolution in Brazil*, 1, p412.
[291] Guattari, *Molecular Revolution in Brazil*, 1, p412.

In line with his previous encouragement to experiment, Guattari extends his reasoning by saying to do 'something *different*'[292] that departs from the stock 'standard labels'[293], whether political or otherwise. Guattari cites numerous intervening systems that undermine the cartographies of control in capitalistic societies. Informatics, like the media, is a key concern for Guattari. Despite cautioning us against the use of informatics and systems that reproduce the same—namely, those of semiotics and significations—systems that reinforce the pragmatics of language and all the problematics this entails, this is not because Guattari is a technophobe. Quite the opposite, Guattari has great foresight. Be it the 'Walkman'[294], which was a revolutionary and maligned device at the time of writing this book, or the advances in radio technology, which were equally revolutionary at the time and whose impacts were little understood, Guattari believes these techno-systems have the potential to be the terminals for the molecular revolution. He has cautioned us previously that technologies have a double-edged sword and that they are also semiotising machines; however, he notes that:

> *I don't think that scientific progress and technology are necessarily accompanied by a reinforcement of the schiz in relation to the values of desire, of creation.* On the contrary, I believe that it's necessary to use machines, all machines, concrete and abstract, technical, scientific and artistic, to do much more than revolutionize the world: to recreate it from point to point.
>
> […] The increasing artificial character of the processes of subjective production could very well be associated with the new forms of sociability and creation. That's where we could find the "cursor" of the molecular revolutions that I talk about nonstop, at the risk of breaking my friends' eardrums.[295]

Guattari argues that technological advancement, and hence its technics, doesn't necessarily alienate us from desire and creativity. Instead, he sees machines (both concrete and conceptual) as tools that can help recreate the world in new ways. He suggests that even as subjectivity becomes more 'artificial' through technology, this can lead to new forms of social connection and creativity, which is what he means by 'molecular revolutions.'[296] This is a hopeful view of technology's relationship to human desire and social transformation, in contrast to more pessimistic perspectives that view technology as inherently alienating. This becomes another significant underlying theme in this dissertation when considering subjectivity and the third-thumb. With all these tools and ideas on subjectivity at hand, Guattari forges a very optimistic and realistic way to bring about change, one that is centred on the creation of flourishing, broader relations in understanding both internal and

[292] Guattari, *Molecular Revolution in Brazil*, 1, p407.
[293] Guattari, *Molecular Revolution in Brazil*, 1, p407.
[294] Guattari, *Molecular Revolution in Brazil*, 1, p406.
[295] Guattari, *Molecular Revolution in Brazil*, 1, p408.
[296] Guattari, *Molecular Revolution in Brazil*, 1, p408.

external (infra-personal and extra-personal) aspects. In the adaptation and adoption of such intrinsic modes of operation at the molecular level, hopes are held that change occurs one atom at a time to bring about a new modality of existence. One that supersedes the mundane and model of individuation. It is hoped that this desire will emanate a rhizomatic and transversal outreach, fostering a new zest for life. This new revolutionary wave ushers in Guattari's concept of new smoothness (both in space and time), characterised by a rich, open, and willful way of cooperation between all ecologies and contexts.

Guattari's concept of new smoothness represents a transformative state where desire and love can move beyond rigid institutional structures. This smoothness enables multiplicities—becoming-woman, becoming-plant, becoming-animal, becoming-cosmos—to emerge through fluid exchanges between molecular and molar forces (transversality). Rather than destroying social structures, it creates possibilities for authentic expression while maintaining productive engagement with society. The new smoothness ultimately offers a path toward liberating human desire and creativity from institutional constraints without requiring complete withdrawal from social systems.

A new smoothness?

Rolnik is not so stoic as Guattari; she even questions the 'new smoothness'[297] and potentiality of the processes of singularization in the expressions of molecular becomings in a certain type of deterritorialising love that Guattari has described. Rolnik is abrogating any possibility for what she refers to 'an empty repetition of the post-Fordist conjugal cell and its Hollywodian characters—a certain figure of man, a certain figure of woman; a certain heterosexuality – entirely devoid of sense.'[298] From this ledge, she launches into a monologue, recounting the story of Penelope and Ulysses, the farce of their co-dependent existence, and the rituals of their destructive relationship. They are condemned to destroy not only each other's happiness but also 'imprisoned in their conjugal cells.'[299]

For Rolnik, other frequencies of the concept of love lay on a wider spectrum and should be explored as alternatives. To demonstrate her point, she cites 'Ridley Scott's *Blade Runner*' [300] and the complex struggle of the 'Replicants',[301] the human cloned androids designed to satiate the appetites

[297] Guattari, *Molecular Revolution in Brazil*, 1, p416.
[298] Guattari, *Molecular Revolution in Brazil*, 1, p417.
[299] Guattari, *Molecular Revolution in Brazil*, 1, p422.
[300] Guattari, *Molecular Revolution in Brazil*, 1, p423 & p93. Released in 1992 is a film based on "the novel *Do Andriods Dream of Electric Sheep?* by phillip K.Dick (1968)"
[301] Guattari, *Molecular Revolution in Brazil*, 1, p423.

of the 'capitalistic bachelor machines'[302]. The humanoids Rolnik refers to were invented to become slaves to a market-driven economy of desire, a type that Guattari and Rolnik have so well explained up to this point, as the reductionist, all-encompassing definition of desire circumscribed in capitalistic systems. Rolnik summarises the movie's plot as she explains how the replicant's lifespans have been limited so as not to allow them to replicate. Instead, she says, they are condemned to slavery and a life span that expires and extinguishes so as not to allow shoots of possible affectual existence that their artificial intelligence may have otherwise afforded them.[303] But as Rolniks explores the book's narrative, she explains that the replicants don't relent; they escape and mount a revolution of sorts. Deckland, the freelance assassin hired 'by the enterprise to eliminate the replicant and their rebellion'[304], falls in love with Rachel, a replicant, in an 'awakening of the vulnerability'[305] to the nature of his mission. The two now '[a]ccomplices and lovers, they leave together',[306] having reigned victorious over the human models of love and its capitalistic irrationalities, establish a new type of conjugal love, one between a human and a humanoid-android. Here, new territories of love are formed 'beyond the Ulysses/Penelope couple and their *all too human* love.'[307] Rolnik prosaically describes this openness to the possibilities of territories beyond those of the capitalistic order, saying, 'we dream, above all, of something beyond capitalistic bachelor machines, and their voluptuous abandon to the exploitation of their own vital energy of creation by the IWC.'[308] Rolnik proposes moving beyond two opposing models: either the enclosed attachments of conjugal territory (as seen in Penelope and Ulysses) or complete detachment (as exemplified by the bachelor machine). She suggests exploring territory beyond these traditional models of relationships. She favours a more free affectual territory created by the characters in Blade Runner, where '*something beyond man (human and /or unhuman)*'[309]. In these territories of emancipation of multiple alternative ways of being in love, one that escapes the instrumentality of market forces that so often fortifies desire as belonging to the logic of labour and capital, into openings for conjugality. For Rolnik, it is not about a total abandonment of all our current states of encounter but rather a foundational virtue to discover 'the otherness of the world, allowing the affects mobilised by this openness to deterritorialize us.'[310] The undoing of our desires and redoing in flights of affectual attraction may not necessarily preclude the Penelope/Ulysses models of

[302] Guattari, *Molecular Revolution in Brazil*, 1, p424.
[303] Guattari, *Molecular Revolution in Brazil*, 1, p424.
[304] Guattari, *Molecular Revolution in Brazil*, 1, p425.
[305] Guattari, *Molecular Revolution in Brazil*, 1, p425.
[306] Guattari, *Molecular Revolution in Brazil*, 1, p425.
[307] Guattari, *Molecular Revolution in Brazil*, 1, p425.
[308] Guattari, *Molecular Revolution in Brazil*, 1, p425.
[309] Guattari, *Molecular Revolution in Brazil*, 1, p425.
[310] Guattari, *Molecular Revolution in Brazil*, 1, p426.

conjugality, nor the bachelor machines, or the partly replicant investments in the economy of desire but those that exceed them. Instead, our awareness of such new territories for love suggests Rolnik may give us the fortitude and earnestness to face the affects of encounters that 'come together in us in different degrees, almost ineffable, a *new smoothness* is already emanating.'[311]

Conclusion

This exploration of the concepts that emerge in *Molecular Revolution in Brazil*, has allowed me to present the complex ideas underlying Rolnik and Guattari's thinking on subjectivity. Their psychoanalytical approach offers insight into the various ways society, politics, and the economy are intertwined with the most fundamental aspects of the subjective unconscious. The exploration has also allowed me to introduce the reader to various subthemes and contexts in which these two psychoanalysts establish their ideas, often through a critique of commonly held assumptions or truths about subjectivity. The exploration of the book *Molecular Revolution in Brazil* introduces us to various terms and concepts that underpin Guattarian subjectivity. Most, if not all, explore the granularity of Rolnik's and Guattari's ideas on subjectivity by exploring the dimensions that frame and explain it. This includes ideas such as schizoanalysis, machinic, molecularity, group therapy, and subject groups (the process of singularization), transversality, revolution and creativity, and the new smoothness. These subthemes also touch on important concepts related to the body, the unconscious, rhizomatics, IWC, technology (technics of augmentation), desire, semiotics, and assemblages of enunciation. Yet, when it comes to the underlying concept of molecularity, there is a realisation that the notion of transversality becomes the foundation for free and autonomous subjectivity. Although the term 'transversality' is not always used explicitly, most, if not all, of these concepts can be traced back to its conceptual roots. The various ideas I've discussed throughout also branch and relate to the processes of transversality. This notion that transversality is the undergirding vector of transformation becomes very clear through reading Guattari's foundational texts written a decade before *Molecular Revolution in Brazil,* in texts such as *Psychoanalysis and Transversality Texts and Interviews 1955-1971* (originally published in French in 1972) and also *The Molecular Revolution, Psychiatry and Politics* (also first published in French in 1977). Transversality becomes the engine room for the mobilisation process that brings into action the various forces underlying the numerous themes of schizoanalysis, including the machinic and its assemblages, group therapy, molecular revolution, and creativity, ultimately bringing into force the new

[311] Guattari, *Molecular Revolution in Brazil*, 1, p426.

smoothness. It is this recurring, overarching theme that underwrites Guattari's earlier work, found in Rolnik and Guattari's collaboration in the book *Molecular Revolution in Brazil*, which forms the logic of exploration when examining the various sub-themes identified here. It will form a key basis for exploring the role of subjectivity in relation to technologies, such as the third-thumb, which will be the focus of the following chapters (Chapter 4 Series: A-E).

Chapter 3 - The field of Supernumerary Robotic Fingers (SRF) and its many manifestations

Introduction

Given the aim of this dissertation to bring together the disparate fields of Rolnik and Guattarian subjectivity and Supernumerary Robotic Fingers (SRF), this chapter explores existing research on the technics related to the SRF and the paradigm of a third-thumb. This review examines the most relevant papers on the topic from the past decade and a half. However, given the nascent nature of the field, most significant developments have occurred within the past nine years, and the literature prior to this period is scarce. I begin with perspectives on the evolution of the human hand, a section that is heavily indexed due to the chapter's length. Methodologically, this chapter examines the field of SRF without the lens of subjectivity. This approach enables us to uncover and explore unexpected intersections in the research presented in the following chapters, rather than fixating on what might be the most obvious (habitual) points of intersection. Herein, I also explore whether we are truly ready to have a functional third-thumb and assess our current progress toward this goal.

This chapter requires the reader's patience, as it necessarily proceeds through device-by-device analysis, examining the most significant aspects of each research project that will become points of intersection in future chapters of this dissertation. The exploration also provides the reader with a sense of the multifaceted dimensions of the field, extending beyond the research itself. It establishes both the thinking within the field and how this area of study is organised.

A perspective on the evolution of the human hand

The human hand, often celebrated as the pinnacle of evolutionary development, presents an intriguing paradox in evolutionary biology. Rather than being highly specialised, it represents what John Napier [312] described as a remarkably primitive structure characterised by five relatively equal digits. This 'primitive' nature is further elaborated in Napier's posthumously published work *Hands*[313] (1980). Coupled with its sophisticated neural integration, the hand enables two fundamental grips—

[312] Tracy L. Kivell et al., "On Primitiveness, Prehensility, and Opposability of the Primate Hand: The Contributions of Frederic Wood Jones and John Russell Napier," Developments in Primatology: Progress and Prospects (United States: Springer New York, 2016), p11.
[313] John Napier and Russell H. Tuttle, *Hands*, Revised Edition ed., Princeton Science Library, (Princeton University Press, 2021).

the power grip and precision grip—that have been instrumental in human technological development. The discovery of *Zinjanthropus* in 1959 by the Leakeys challenged previous assumptions by suggesting that the hand's current form predated significant cerebral expansion, indicating that manual dexterity preceded rather than followed enhanced cognitive capacity.[314] As Lemelin and Schmitt argue in *The Evolution of the Primate Hand*[315] (2016, Chapter 1: "On Primitiveness, Prehensibility, and Opposability of the Primate Hand"), comparing human hands to the highly specialized appendages of other primates reveals that our hand's generalised form represents not advanced evolution but rather an arrested development that proved remarkably advantageous for tool manipulation and cultural development. For a detailed explanation of these important ideas that help us contextualise the social, cultural, and political dimensions of the development of the hand, please refer to Appendix 2.

Scope

The scope of this dissertation is to review innovations in design, considering the evolution of technology and its parallels to biological evolution, as well as its impacts, as discussed above. This includes the types of hands and fingers being invented through the melding of technology and biology, as well as the cultural impacts they may have. The work herein considers current research in modelling an extra robotic finger. Supernumerary Robotic Fingers (SRFs) or Extra Robot Fingers (ERFs)[316] or (XRAs)[317] and their various proprietary names are used by various researchers who have developed their designs. The work in this field is highly technical and does not readily lend itself to philosophical discourse that addresses the social, political, and economic impacts on subjectivity. However, it is necessary to cover the structures that give rise to the field SRFs, as well as the semiotic and portrayal motifs that run through the various designs and the people behind the research. This will provide us with more scope for appreciation in the discussion that later brings together the association between Suely Rolnik and Félix Guattari's psychoanalysis and the particularities of the SRFs, as well as their impact upon and through subjectivity. Therefore, this section, while admittedly dense in its theoretical articulations, provides the indispensable conceptual foundation upon which subsequent arguments are constructed. The rigorous exposition

[314] John Napier, "The Evolution of the Hand," *Scientific American* 207, no. 6 (1962), http://www.jstor.org.ezproxy.library.sydney.edu.au/stable/24936385.
[315] Kivell et al., "On Primitiveness, Prehensility, and Opposability of the Primate Hand: The Contributions of Frederic Wood Jones and John Russell Napier," p7.
[316] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p624.
[317] Giulia Dominijanni et al., "The neural resource allocation problem when enhancing human bodies with extra robotic limbs," *Nature machine intelligence* 3, no. 10 (2021): p850, https://doi.org/10.1038/s42256-021-00398-9.

of these foundational concepts, though demanding sustained intellectual engagement, is methodologically necessary to establish the analytical framework through which we may comprehend the broader theoretical terrain.

The literature on SRFs is situated within a larger body of work, mainly entwined the other types of wearable supernumerary limbs (SRL's), including the plethora of work on prosthetics for replacing lost limbs due to congenital or musculoskeletal injury[318] and exoskeletons for supporting the movement of limbs with low or lost function in rehabilitation. The context for these innovations is at once medical necessity, workforce efficiency[319] and productivity. This falls into the Marxist purview of the capitalistic need to drive workforce efficiency, necessitating systems like *exosuits* designed to 'empower human natural movement'[320] as observed by Prattichizzo et al., who argue it helps individuals in the workplace to carry heavier loads and work harder. This is one of the primary reasons for initiating research in the field—to support people in the workplace and industry. There is no argument for the value of such work in the medical field, which helps users suffering from injuries achieve richer, more fulfilling lives. The drive for productivity is questionable, which becomes a point of contention in this thesis. Returning to my focus in this dissertation, however, is the augmentation of an independent SRF for healthy individuals, with a focus on the current state of affairs, existing design ontologies, technologies, and wearability. The research project cannot provide such a clear line of delineation as to why some SRFs are designed, because it is often not clear from the literature why some researchers have embarked on their respective research. This dissertation, however, looks specifically at SRF for augmentation. Therefore, the history of how and why various projects have developed from either a medical perspective or others from an artistic field is noteworthy because it shows the level of cross-pollination in the inception of ideas. This is important because it provides insight into the mindset and direction of some SRF projects, allowing the dissertation to read between the lines and critically analyse the various projects and their motivations, which have a direct link to subjectivity. Some researchers have made significant technological advances in prosthetics and utilised their mechatronics for futuristic purposes, such as augmentation, as seen in the work of Danielle Clode (also known as Dani Clode).[321] Despite the motivation or use of designs, technical advances are important because they contribute to advancing an SRF or third-thumb that

[318] Ziyu Liao et al., "A human augmentation device design review: supernumerary robotic limbs," *Industrial robot* 50, no. 2 (2023): p256, https://doi.org/10.1108/IR-03-2022-0079.
[319] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p256.
[320] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," pg1.
[321] Paulina Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," *Science robotics* 6, no. 54 (2021), https://doi.org/10.1126/scirobotics.abd7935. And "Dani Clode An augmentation designer exploring the future body," 2012-2022, accessed 10/07/2024, 2024, https://www.daniclodedesign.com/.

can become easy to augment and eventually ubiquitous. From the outset, it is essential to note that most of the work in this field is derived from research in patient rehabilitation, specifically the use of prosthetics to restore lost hand function. This has its limitations, as shall be explained later, because replacing lost function is physiologically and anatomically very different from augmenting one. Despite this, a researcher working in the medical rehabilitation field can inspire and cross-pollinate research in robotics for work or future endeavours of people with extra fingers. Hence, these innovations, which have become the focus of this dissertation, have come to cross-pollinate and contribute to the design edifice we are seeking in the SRF designs, ultimately changing the nature of the hand and augmenting it with another thumb or finger.

It is worth emphasising that not all technologies developed in the field of SRLs apply to the field of SRFs, as alluded to when discussing SRLs. SRFs are specialised areas that utilise specific technologies, enabling hand- and finger-like movements that require very specific strength, mapping, coordination, and quicker and finer movements. Technologies used to replicate or build other body parts, such as extra arms and legs, have the potential to afford a new path of research into SRF functionality, but are not all transferable to the field of SRFs.

I shall be exploring what is currently in the field, with a particular bias towards certain designs for their aesthetic, functionality, technical design inspirations, and visionary futuristic outlook, where a sixth finger or a third-thumb would become an indistinguishable feature of the hand/body.

Four noteworthy reviews

My exploration of SRFs is structured around four comprehensive reviews published between 2021 and 2023, which together capture over two decades of SRF development. These pivotal reviews are: Liao et al.'s device design-focused review (2023, Industrial Robotics) [322], Yang et al.'s future outlook paper (August 2021, IEEE Xplore)[323], Prattichizzo et al.'s analysis (September 2021, Progress in Biomedical Engineering)[324], and Tong and Liu's foundational review (May 2021, IEEE/CAA Journal of Automatica Sinica)[325]. Whilst these reviews are predominantly technical in nature, focusing on mechatronics and robotics, my analysis extracts their broader implications for wearable technology

[322] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p256.
[323] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook."
[324] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives."
[325] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs."

and cultural acceptance. A comprehensive discussion of these reviews and their significance for SRF development is presented in Appendix 3.

SRL classification

As already mentioned, SRF designs range from an extra finger to two or more; some are even designed around a whole hand. Liao et al. summarise current innovations, citing the major prototypes or third-thumb paradigms so far in existence, suggesting:

> SRFs play the role of human fingers, they can achieve the movement function of the natural fingers. Unlike the hand exoskeletons, SRFs have robotic fingers with independent movements, and they can strengthen the wearer's single hand grasp ability by collaborating with the wearer's natural finger (Hussain and Prattichizzo, 20200). Moreover, the SRFs do not always have two robotic fingers; it can be a single finger (Hussain *et al.*, 2015a), two fingers (Ort *et al.* 2015) or even more. Almost all SRFs are worn on the palm or wrist, and their size and weight are strictly constrained for wearing comfort and safety.[326]

The number of fingers is not necessarily the issue of focus; rather, the focus rests on the finger or fingers' functionality and ease of use. Prattichizzo et al. describe their current vision of SRFs in this way:

> Supernumerary robotic limbs (SRLs) are wearable robots designed to enhance the sensorimotor abilities of humans. SRLs can be used to compensate for lost function in patients with motor deficits and, more in general, to augment the sensorimotor capabilities of humans to interact with the environment.[327]

Giving a background to the history of SRFs (embedded in SRL domain), Liao et al. argue that the

> original prototype of SRLs was proposed by MIT in 2012, and they successfully applied it to assist workers to hold a workpiece during drilling (Llorens-Bonilla *et al.*, 2012). Moreover, they designed the SRLs to support the aircraft assembly workers in uncomfortable postures and reduce the loads on workers' leg joints (Parietti and Asada, 2014; Parietti *et al.*,2014, 2015; Parietti and Asada, 2016).[328]

Liao et al.'s review papers show that SRLs are used in various industries, including industrial manufacturing, medical rehabilitation, life services, construction, and agriculture, among others.[329] In their review, Tong et al. referred to the 'World Labor Statistic database' and the number of

[326] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p258.
[327] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," pg1.
[328] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p256-57.
[329] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," pg 257.

injuries that could be avoided using wearable technologies. [330] This obsession with productivity is interesting and prevalent among researchers in the field. The focus on increasing labour productivity justifies the researcher's aims and serves as the basis for the projects explored in nearly all the papers reviewed in this literature review. There is a broader social and political question at stake here. This shall be considered in later chapters that analyse these researchers' epistemic approach. (It is also patently relevant to the domain of subjectivity discussed in the previous chapter and its relation to IWC (Integrated World Capitalism), the grid of control that envelops subjectivity).

Areas for research undertaken and institutions involved

Tong et al. point out, 'current research on SRLs [which includes SRFs] is currently in its infancy, and there are still many problems that have not been resolved'.[331] The field of SRLs (and thus SRFs) encompasses a wide range of disciplines, including engineering and mechatronics, neurosciences, cognitive science, design, medical engineering, robotics, human-robot collaboration, manufacturing, brain-computer interfaces, biomechanics, medicine, and other related fields. However, most of the research in this section focuses on papers from the biomedical engineering and mechatronics fields, as well as the designs they have undertaken. In the review by Tong et al., a mind map was compiled connecting all the various fields of key technology in the field of SRLs that require further research, as shown in Figure 1.[332] Most, if not all, of these technologies, referred to here for SRLs, are constituents of SRFs.

[330] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p929.
[331] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p941.
[332] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p942. Figure 9. Key technolgies of SRLs.

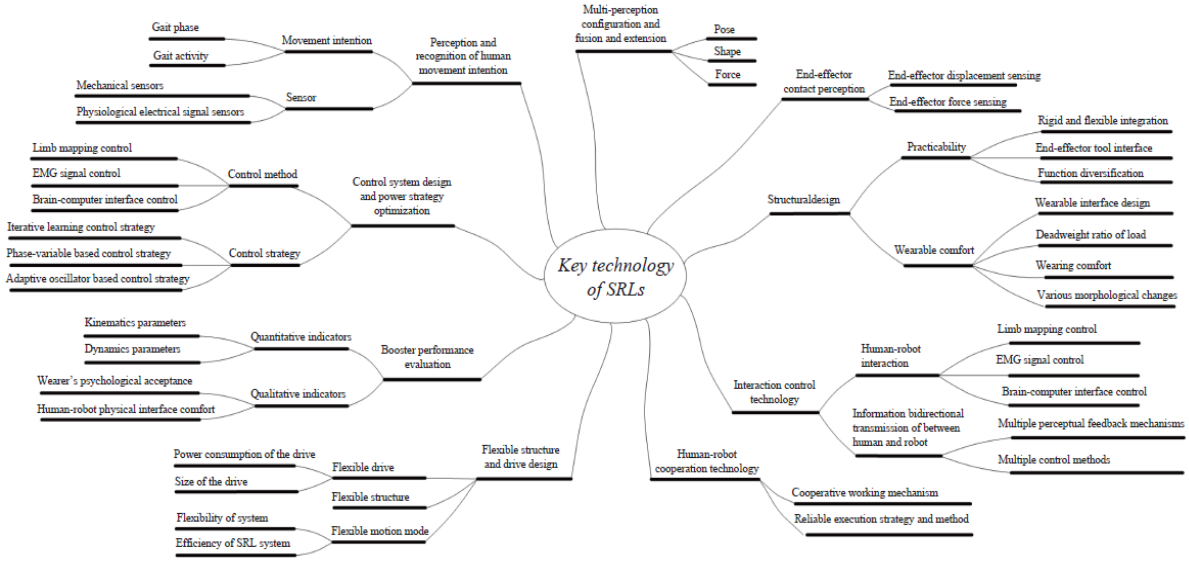

Figure 2 - Key technologies of SRLs (and SRFs) taken from Tong et al.[333]

A very interesting field that intersects with the research of SRFs is the area of research examining the role of neural perception and neural augmentation, which is not depicted in Tong et al.'s diagram. This wide area of research is the focus of philosophers and neuroscientists, encompassing another very important field that is still in its infancy, based on the rubber hand illusion (RHI). It is a significant area of importance but shall be out of scope for this dissertation, though references will be made to it (at a very high level). The neurological response to such phenomena will only be referred to enough to uncover the current status of the research and its impact on the neurocognitive limitations of SRF for human augmentation or 'human body enhancements' as suggested by types of research such as those by Dominijanni et al.[334] Giulia Dominijanni, in collaboration with notable researchers in SRF augmentation, wrote a review called 'The neural resource allocation problem when enhancing human bodies with extra robotic limbs' in the journal Nature Machine Intelligence, which gives a picture of these challenges. As Prattochizzo et al. suggest, '[n]euroscientific considerations on the 'Neural Resource Allocation' problem' are important where SRF artifacts with sensorimotor control of SRFs are considered.[335] This will be examined later when considering whether humans possess the neural capacities to exceed the current neural load within or adjacent to the same schema of body mapping, which entails our current standard neurophysiology using ten fingers only. This is also a vital challenge that requires substantial neural

[333] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," Figure 9, p942.
[334] Dominijanni et al., "The neural resource allocation problem when enhancing human bodies with extra robotic limbs."
[335] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p2.

allocation capacity, especially when considering end-to-end integration with 'bidirectional human-machine collaboration'[336] systems. This increases the neural load to encompass all capacities, feelings of touch, and their neural responses to the external world, utilising an augmented feeling that mimics the sensation and responses of a biological native finger.

In their review, Tong et al. highlight the important institutions that are repeatedly cited during research on the topic of SRLs. Based on their analysis of noteworthy countries and institutions

> [t]he United States, Japan and China have the most extensive research in the field of wearable external limb robots, followed by Italy, South Korea, Singapore, Germany, the U.K., and other countries. Harvard University, Massachusetts Institute of Technology, Lorean Science Research institutes, Harbin Institute of Technology, and Chinese Academy of Science have made outstanding contributions in this field.[337]

However, as we shall see from the research and discussions for this review on SRF, the subset of SRLs is narrowed down to particular researchers and institutions that focus on the specifics of SRF projects. This will become apparent as the review unfolds, and similar names of researchers will reappear. In this review of this dissertation, these projects and their technologies will form the centre of discussion, and I shall try to cover as many currently existing projects as possible.

Various dimensions of SRFs

Ontological structures and wearability

Liao et al.'s focus on device design is the only review that succinctly characterises the structure of an SRL as being one 'divided into three parts':[338] a base that is wearable and attaches to the body, a limb that extends from the base, and end-effector which is the point of contact with objects external to the body, and in the environment. This is a good starting point for thinking about SRLs and SRFs. Tong et al. concentrate on reviewing eleven prototypes[339] or SRF artifacts in their analysis, as shown in Figure 2.

[336] Dominijanni et al., "The neural resource allocation problem when enhancing human bodies with extra robotic limbs," p850.
[337] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p930.
[338] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p259.
[339] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p932. Figure 4.

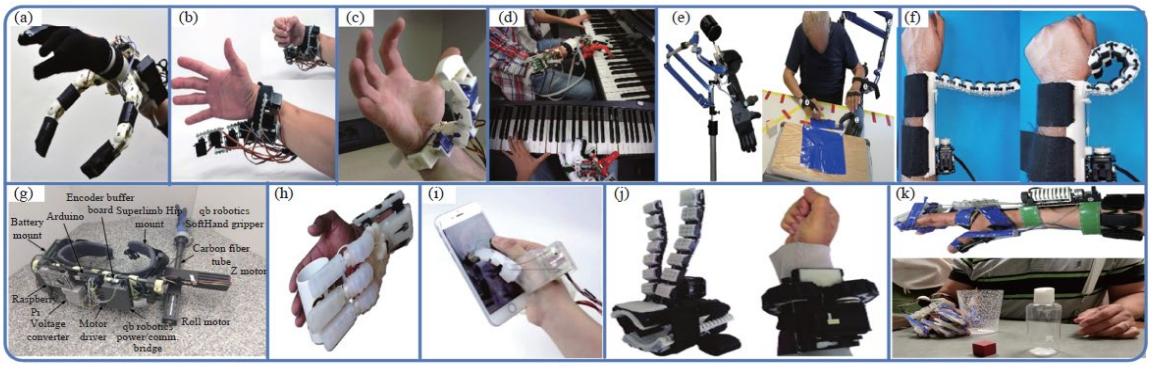

Figure 3 - Eleven prototypes reviewed by Tong et al., taken from Tong et al.'s paper[340]

Tong et al. note 'that over the past decade, researchers have begun to focus on SRLs, which shows a trend of vigorous development.'[341] They outline the virtues of SRLs and continue to explore SRFs in a separate section, further dividing SRFs into two categories that distinguish them as either a 'rigid supernumerary robotic finger' or a 'soft supernumerary robotic finger'.[342] This is another way to categorise the profile of SRFs. This ontological structural difference distinguishes and reviews the eleven prototypes they cite through this lens. In the table shown in Table 1 (highlighted in yellow) of their paper called 'Classification of SRLs'[343] Tong et al. neatly summarise the research institution where development of various prototypes took place, their ontological structures/features, be it soft or rigid, where the SRF is worn on the body; be it forearm, wrist or hand; the technological control strategy used to mobilise it, and a usability function termed 'Auxiliary type' which they broadly use to define its use for work or daily support. It is worth noting that these SRFs have limited functionality and cannot replicate the full functionality of a true biological thumb, which remains the biggest challenge facing the creation of an indiscernible SRF. This issue will be explored further when describing the discrete and particular design features of the SRFs reviewed in more detail.
Prattichizzo et al. make an additional taxonomical distinction in the field of SRFs. In addition to the softness or rigidity of SRFs, they distinguish 'actuation systems' (either fully actuated or underactuated).[344]

[340] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," Figure 4, p932.
[341] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p930.
[342] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p932.
[343] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p933. Table I
[344] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p2.

Table 1 - Tong et al.'s eleven SRFs reviewed with their classification particularities taken from Tong et al.[345]

CLASSIFICATION OF SRLS

Research institute	Ontological structure	Wear	Control	Auxiliary type
	Rigid supernumerary robotic limb [5], [18], [19], [36], [38]	Waist		Work auxiliary
	Rigid supernumerary robotic limb [58]	Shoulder	Limb mapping	Work auxiliary
	Rigid supernumerary robotic limb [3], [4]	Waist		Work auxiliary
	Rigid supernumerary robotic limb [33], [65]	Back	Limb mapping	Work auxiliary
Massachusetts Institute of Technology	Rigid supernumerary robotic limb [20]	Back		Work auxiliary, Daily support
	Rigid supernumerary robotic finger [5], [82]	Forearm	Limb mapping	Daily support
	Rigid supernumerary robotic limb [66]	Back		Work auxiliary
	Rigid supernumerary robotic finger [84]	Forearm	EMG signal	Daily support
	Rigid supernumerary robotic finger [23]	Forearm	EMG signal	Daily support
	Soft supernumerary robotic finger [87]	Forearm		Daily support
	Soft supernumerary robotic finger [88]	Forearm		Daily support
Keio University	Rigid supernumerary robotic limb [51]	Waist	Limb mapping	Daily support
Royal Institute of Technology	Rigid supernumerary robotic limb [75]	Waist	Limb mapping	Work auxiliary, Daily support
Cornell University	Rigid supernumerary robotic limb [64]	Forearm		Work auxiliary, Daily support
Italian Institute	Rigid supernumerary robotic limb [69]	Back		Work auxiliary, Daily support
Italian Institute of Technology	Soft supernumerary robotic finger [42], [43], [49]	Forearm	EMG signal	Daily support
Georgia Institute of Technology	Rigid supernumerary robotic limb [40], [46], [90]	Shoulder	EMG signal	Daily support
Imperial College London	Rigid supernumerary robotic finger [86]	Hand	Limb mapping	Daily support
Arizona State University	Soft supernumerary robotic limb [78]	Back		Work auxiliary, Daily support
Waseda University	Soft supernumerary robotic limb [80]			Daily support
Ritsumeikan University	Rigid supernumerary robotic limb [70]	Waist		Work auxiliary, Daily support
Seoul National University	Rigid supernumerary robotic limb [71]–[74]	Waist		Work auxiliary
Nanyang Technological University	Rigid supernumerary robotic limb [24]	Feet	EMG signal	Work auxiliary
Montpellier University	Rigid supernumerary robotic limb [22]	Waist		Work auxiliary
Canadian Interdisciplinary Institute of Technology Innovation	Rigid supernumerary robotic limb [25]	Waist		Work auxiliary, Daily support
National University of Singapore	Soft supernumerary robotic limb [76]	Waist		Work auxiliary, Daily support
Technical Institute of Genoa	Rigid supernumerary robotic finger [21], [69]	Forearm	EMG signal	Daily support, Medical assess
University of Siena	Rigid supernumerary robotic finger [85]	Forearm	Limb mapping	Daily support, Medical assess
Columbia University	Soft supernumerary robotic finger [89]	Forearm	EMG signal	Daily support, Rehabilitation
Harbin Institute of Technology	Rigid supernumerary robotic limb [62]	Back		Work auxiliary
	Soft supernumerary robotic limb	Back		Work auxiliary, Daily support
Nankai University	Rigid supernumerary robotic limb			Work auxiliary
South China University of Technology	Rigid supernumerary robotic limb	Back		Work auxiliary
Tsinghua University	Rigid supernumerary robotic limb [14]	Back	EMG signal	Work auxiliary, Daily support

The systems that drive movements, such as flexion and extension, are controlled by configuration systems of 'drives'[346] that control actuation. Some use the minimal number of drives to create movements in the SRFs, while others use many, depending on the design and its functionality. Liao et al. and other researchers use the following distinction in SRFs to make two systematic categories: ' fully driven and under driven'[347] SRFs. The fewer the drives, the less the weight of the SRF, and the less use of servo motors that make up the drives means less mass and size. These types of drive

[345] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p933.
[346] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p259.
[347] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p259.

systems, also known as underactuated systems, utilise lever arrangements, which mimic the function of wire systems to bring about movement, much like the real tendons of the human hand.

In contrast, actuated systems utilise a servo motor at each joint, which makes them heavier for the user. Actuated or fully driven systems can achieve higher load capacity and grip, but their weight can make them uncomfortable due to wearability issues. As Prattichizzo et al. suggest;

> [w]hile the underactuated finger results in being lighter, more portable, and easily adaptable to different objects, the fully actuated version allows a more precise control of the finger trajectory and tighter grasp.'[348] In general, Liao et al. noted that load capacity in SRFs is 'relatively weak'[349]

The range of movement at the joints' angles is referred to as degrees of freedom (DOF). A human hand usually is said to have 27 degrees of freedom (DOFs)[350]. The DOF varies depending on the design and type of joints and drive systems used to operate SRFs. This will become more evident as we refer to it while examining specific SRF artifacts and paradigms during this review. The preference among researchers and research reviews suggests that 'under-driven [under actuated] design schemes, cable—and pneumatic-driven' is the preferred mainstream approach, as endorsed by Liao et al.[351] They also preface this because the actuator or drive sits separately from the joint, mostly closely strapped at the point where contact is made between the SRF and the body. This positioning of the servo motors at the periphery of the SRF, often stabilised by the body, allows for the SRF to be secured more closely to the arm or wrist, transmitting and radiating the drive's power through ropes and air circuits, increasing the wearability of the design.[352] The disadvantage of such a system is that it increases the difficulty of actioning speed and precise control, resulting in lag and inertia. On the other hand, fully driven systems or fully actuated SRFs exhibit higher functionality, more responsive reflexes, and greater precision.[353] Prattichizzo et al. summarise it in this way:

> When designing SRLs, the choice of materials, actuators, and sensors usually aims at achieving a desired trade-off between wearability and dexterity of the robot. On the one hand, articulated and mostly rigid structures with as many degrees of freedom (DoFs) as degrees of actuation (DoAs), i.e. fully actuated, can be very precise and reach a variety of configurations but require a higher number of motors, sensors, and batteries, which can hinder the wearability of the device. On the other hand,

[348] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p7.
[349] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p259.
[350] Zhou Hao et al., "A Novel Monolithic Soft Robotic Thumb for an Anthropomorphic Prosthetic Hand," *IEEE robotics and automation letters* 4, no. 2 (2019): p602, https://doi.org/10.1109/LRA.2019.2892203.
[351] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p260.
[352] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p262.
[353] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p261.

light, complaint, underactuated structures can be more wearable at the price of reduced functionality and mobility.[354]

Liao et al. present us with a table (Table 2), which they have put together, showing all the types of SRFs they have investigated, with a particularly detailed focus on the DOF and the type of drive and where the artifact is positioned on the body. From this, we can see that the SRFs (mixed in with SRLs) are generally identified by their positioning on the body, most commonly on the wrist, forearm, or palm. They have carefully documented the various projects and their authors, including the control interface with an additional feature of capturing the feedback modality, which will be referred to below. Feedback is when mechanical translation of touch, most commonly through pressure sensors, is used at the fingertip to relay messages back to the body.

Table 2 - List of SRFs (in yellow) showing wearing position and motor function and sensor modality for the SRF prototypes reviewed by Liao et al. Taken from Liao et al.[355]

Literature	No.	DOF	Driving	Wear position	Control interface	Feedback modality
Wu and Asada (2014)	2	3	Motor-driven	Wrist	Stretch sensor	Not mentioned
Wu and Asada (2015)	2	2	Cable-driven	Wrist	IMU sensor	Not mentioned
Hussain *et al.* (2015a)	1	4	Motor-driven	Forearm	EMG sensor	Vibrotactile
Ort *et al.* (2015)	2	2	Motor-driven	Forearm	Stretch sensor	Not mentioned
Leigh and Maes (2016)	2	5	Motor-driven	Forearm/wrist	EMG sensor	Not mentioned
Hussain *et al.* (2017b)	1/2	1	Cable-driven	Wrist/forearm	EMG sensor	LED lights
Salvietti *et al.* (2017)	1	4	Cable-driven	Forearm/wrist	EMG sensor	Not mentioned
Cunningham *et al.* (2018)	1	2	Motor-driven	Palm	Flex sensor	Not mentioned
Iii *et al.* (2018)	2	1	Pneumatic-driven	Forearm	Program command	Not mentioned
Leigh *et al.* (2018)	1	1	Motor-driven	Wrist	Multiple interfaces	Haptic
Liu *et al.* (2020)	2	4	Pneumatic-driven	Forearm	Program command	Pressure
Kieliba *et al.* (2021)	1	2	Cable-driven	Palm	Force sensors	Not mentioned
Lee *et al.* (2021)	1	1	Tendon-driven	Forearm	Control box	LED indicators
Umezawa *et al.* (2021)	1	1	Motor-driven	Palm	EMG sensor	Tactile
Parietti *et al.* (2015)	2	3	Motor-driven	Waist	EMG sensor	Not mentioned
Miyazaki *et al.* (2016)	2	3	Pneumatic-driven	Waist	Program command	Not mentioned
Kurek and Asada (2017)	2	2	Motor-driven	Back	Optical force sensors	Not mentioned
Hao *et al.* (2020b,a)	2	3	Motor-driven	Back	Force sensor	Force
Khazoom *et al.* (2020)	1	2	Hydraulic-driven	Waist	IMU sensor	Not mentioned
Wu *et al.* (2020)	2	1	Pneumatic-driven	Waist	Vision sensor	Not mentioned
Leng *et al.* (2021)	1	1	Motor-driven	Back	IMU sensor	Not mentioned

A comparison made by Tong et al. between rigid and soft SRFs assesses the advantages and disadvantages of the two ontological structures and how they have evolved. The distinction between rigid and soft SRFs encompasses identifying the different systems involved in joint control, the weight it places on the user, the balance of stiffness and flexibility in the SRF, and the power-to-load ratio it generates. They even show cognisance of, and are attentive to the 'social and […]psychological burden.'[356]

[354] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p3.
[355] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p260.
[356] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p934.

Tong et al. state that, in their estimation, they favour soft SRFs due to their safety and wearability. They argue that this field of robotics is,

> slowly redefining the research and technology of wearable robots […] including those with silicon-based soft pneumatic actuators and robots that are inherently soft due to their high power-to-weight ratio, innate flexibility, low cost, and high customization, allows for broader applications in the field of wearable robots.[357]

Citing various current papers on the topic, they have collated a table showing the 'Comparison of Rigid Supernumerary Robotic Limbs and Soft Supernumerary Robotic Limbs' seen in Table 3.[358] Prattichizzo et al. extol the virtues of hybrid projects, acknowledging that 'a soft-rigid version' that adopts the best of both worlds would be advantageous. They suggest that these SRFs are 'composed of a rigid part acting as a link, and a flexible part acting as a joint. The compliance introduced in the systems makes the device robust to impacts, light to wear, and easy to control, since it can passively adapt to objects with different shapes.'[359]

Table 3 - Comparison of soft SRLs(SRFs) vs rigid SRLs (SRFs) taken from Tong et al.[360]

	Rigid SRLs	Soft SRLs
Advantage	1) It can provide a large power torque and greatly improve the loading and unloading capacity of human body: 2) It is easy to design a force controller with high bandwidth and performance.	1) Flexible structure, easy to adapt to different movement states of anatomically different people and wearers; 2) Flexible drive, can provide parallel assistance with human muscles/tendons, more in line with human biomechanics: and can move the system weight to the waist of the human body to reduce the inertia of the extremity of the limbs; 3) The system is lightweight and easy to carry and wear.
Disadvantage	1) The non-alignment between the rigid link and the physiological joint will produce an undesired torque of up to 146 N×m; 2) The rigid link will increase the inertia of the extremities, thus increasing the metabolic consumption; 3) The system is large, so it is inconvenient to carry and wear, and easy to lead to the unstable movement of the man-machine system. Generally, crutches are needed.	1) Only one-way assistance (rope drive) can be provided; 2) It is unable to support the weight of the human body, and it is generally impossible to unload the human-robot system.
Applicable population	1) Paraplegic people who cannot walk at all; 2) Patients who cannot support most of their own weight; 3) Military personnel who need to perform long-term weight-bearing exercises.	1) Patients with hemiplegia and residual walking ability; 2) Elderly people with declining exercise function; 3) Healthy people such as individual soldiers and athletes.
Research difficulties	1) Self-alignment and self-adjustment structure design of exoskeleton joint; 2) The realization of load-bearing unloading function and the motion stability control of man-machine system; 3) Ergonomic physical interface comfort level and human power control.	1) Synergy effect analysis between human muscles; 2) High-performance controller design based on flexible materials and flexible drives; 3) Parameters optimization of the booster controller based on human body differences.

Prattichizzo et al. have assembled a group of SRFs that they consider noteworthy for review in their paper. Figure 3 and Figure 4 illustrate these various projects, each with one or more fingers, some of which will be reviewed in detail later. They have also compiled tables with the device name, design function and its actuation system, as well as control and the type of feedback interfaces (Table 4 and

[357] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p932.
[358] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p935. Table II
[359] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p7.
[360] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p935.

Table 5). Domenico Prattichizzo and Ifran Hussain, who have put together a comprehensive volume on SRFs outlining the current research projects in 'Biosystems & Biorobotics, Volume 26', have composed a very useful table to enable us to see and compare the necessary design and functional requirements of 'Soft Supernumerary Robotic Fingers' shown in Table 4.[361]

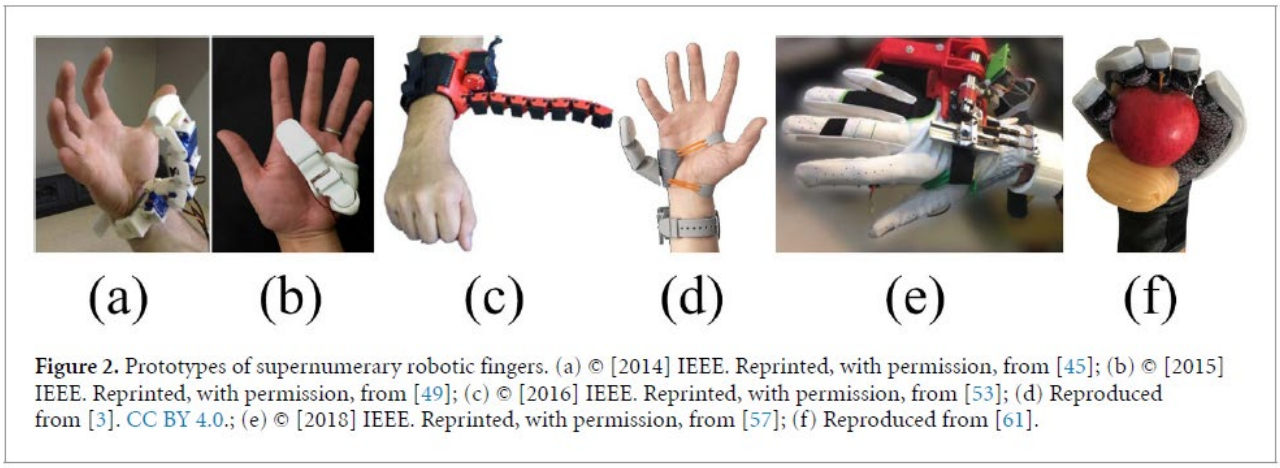

Figure 2. Prototypes of supernumerary robotic fingers. (a) © [2014] IEEE. Reprinted, with permission, from [45]; (b) © [2015] IEEE. Reprinted, with permission, from [49]; (c) © [2016] IEEE. Reprinted, with permission, from [53]; (d) Reproduced from [3]. CC BY 4.0.; (e) © [2018] IEEE. Reprinted, with permission, from [57]; (f) Reproduced from [61].

Figure 4 -SRFs reviewed by Prattichizzo et al. (one finger only) taken from Prattichizzo et al.[362]

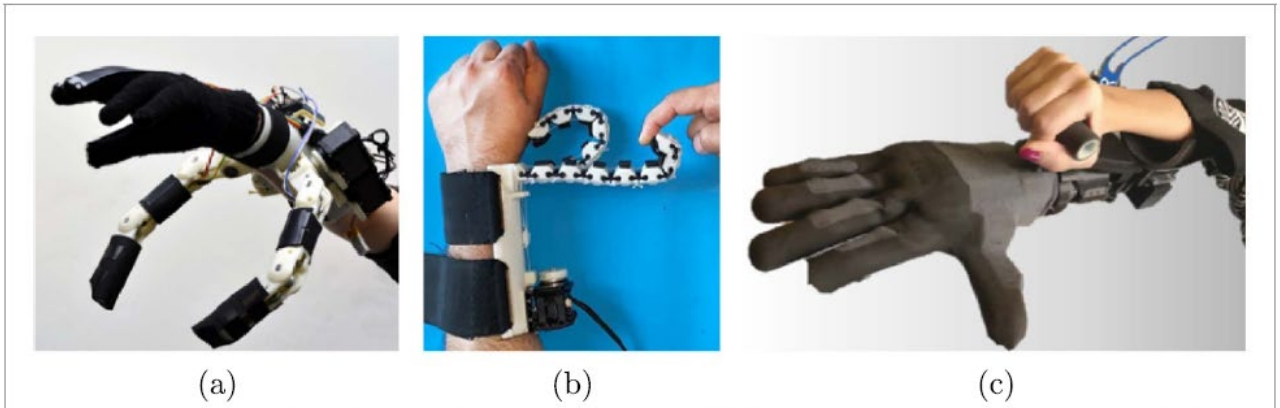

Figure 3. Supernumerary robotic devices with more than one finger. (a) Underactuated supernumerary fingers; © [2015] IEEE. Reprinted, with permission, from [71]. (b) Double Soft-SixthFinger; Reproduced from [75]. CC BY 4.0. (c) SoftHand X; © [2020] IEEE. Reprinted, with permission, from [80].

Figure 5 - SRFs reviewed by Prattichizzo et al. (with more than one finger only) taken from Prattichizzo et al.[363]

[361] Irfan Hussain and Domenico Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, 1st ed. 2020. ed., Biosystems & Biorobotics, 26, (Cham: Springer International Publishing, 2020), p72.
[362] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p7.
[363] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p9.

Table 4 - Main characteristics of mechanical design, actuation system and control/feedback interfaces for supernumerary robotic devices embedding one wearable finger. Taken from Prattichizzo et al.[364]

Device	Design, actuation and sensing	Control and feedback interfaces
Robotic Sixth Finger (2014), Prattichizzo *et al* [43]	Fully actuated device with 4 DoAs (3 for flexion, 1 for abduction/adduction), modular structure made of ABS. Magnetic compatible version proposed in [44].	**Control.** Based on tracking data from the fingers of the augmented hand [43, 45], wearable buttons [46, 47], or two EMG interfaces worn on the arm [48]. **Feedback.** Vibrotactile ring [46, 47].
Extra Thumb (2015), Sobajima *et al* [49]	Fully actuated device with 3 joints (2 flexion, 1 abduction/adduction) and a force sensor at the fingertip. It is worn on the palm.	**Control.** Based on tracking data from the thumb of the opposite hand [49] or through EMG from auricularis muscles [50, 51]. **Feedback.** Tactile feedback through electrical stimulation to the opposite thumb [49, 50, 52], head mounted display to relay position information [50], vibrotactile feedback on the back of the hand wearing the device [51].
Soft-SixthFinger (2016), Hussain *et al* [53]	Underactuated device with 1 DoA for the flexion of 7 joints, tendon driven, modular structure with rigid links and flexible joints.	**Control.** EMG interface worn on the frontalis muscle [53, 54], or wearable buttons [55]. **Feedback.** Visual (LED lights) for EMG control [53], wearable haptic ring [55], vibrating feedback on the occipital area of the head for EMG control [54].
Morphology Extension Kit (2018), Leigh *et al* [56]	Interchangeable modules for building wearable robots. Rigid, modular structure covered with soft material.	**Control.** The robot is controlled through software triggers.
Third thumb (2018), Cunningham *et al* [57]	Fully actuated device with 2 DoAs (horizontal and vertical motions) and a rigid structure.	**Control.** Horizontal movement controlled by the motion of the user's thumb of the augmented hand, vertical DoF controlled by the lifting of the left foot [57]. Both DoFs controlled by moving the foot [58].
Fin Ray sixth finger (2019), Hussain *et al* [59]	Linear actuator for the bending motion. Compliant structure with stiff crossbeams.	**Control.** Push buttons. **Feedback.** Visual (LED lights).
Pneumatic supernumerary finger (2019), Singh *et al* [60]	Soft finger with fiber-reinforced bidirectional pneumatic actuators.	**Control.** Manual setting of the inflating pressure.
Telescopic finger (2020), Gerez *et al* [61]	Telescopic soft finger.	**Control.** Application installed in a smartphone.
Third Thumb (2020), Kieliba *et al* [3]	Tendon driven finger worn on the palm. 2 DoAs (1 for flexion and 1 for adduction/abduction). Motors and batteries worn on the wrist and on the arm, respectively.	**Control.** Pressure sensors taped underneath the big toes of the user's feet. The right toe controls the flexion, the left toe controls the abduction.

[364] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p8.

Table 5 - Main characteristics of mechanical design, actuation system and control/feedback interfaces for supernumerary robotic devices embedding two or more fingers. Taken from Prattichizzo et al.[365]

Device	Design, actuation and sensing	Control and feedback interfaces
Supernumerary robotic (SR) fingers (2014), Wu and Asada [67]	Fully actuated, two fingers having 3 DoAs each. A newer version embeds force sensors and an IMU [68].	**Control.** Based on tracking data from the fingers of the augmented hand [67, 69] or on the arm position [68].
SR fingers with soft inclusions (2015), Ort *et al* [70]	Fully actuated, two fingers having 2 DoAs each. Additional DoA at the base for translation. Textured rubber pads and small air bubbles to increase friction and compliance.	**Control.** Based on tracking data from the fingers of the opposite hand.
Underactuated SR fingers (2015), Wu and Asada [71]	Underactuated device, two fingers having 2 DoAs and 3 DoFs each, cable driven, embedded force sensors.	**Control.** Method exploiting both the grasp synergy and the redundancies in the elbow.
Pneumatic SR fingers (2017), Tiziani *et al* [72]	Three fingers with soft rigidizable phalanges and variable stiffness pneumatic bending actuators. Newer version of the device with two fingers presented in [73].	**Control.** Manual setting of internal pressure.
Double Soft-SixthFinger (2017), Hussain *et al* [74]	Underactuated device, two fingers, tendon driven, modular structure with rigid links and flexible joints. Two DoAs, one per finger [74], or one DoA with a differential mechanism [75].	**Control.** EMG interface worn on the frontalis muscle [74]. **Feedback.** Visual (LED lights) for EMG control [74].
Otariidae-inspired supernumerary flippers (2020), Liu *et al* [76].	Two fingers, 8 DoAs each, soft pneumatic actuators reinforced by fabric inspired to origami and kirigami. Pressure sensor for each actuator.	**Control.** Cascaded control structure: posture-control outer loop, several pressure-control inner loops [77].

Tong et al. have also assembled a group of projects that have piqued their interest in SRFs. As shown in Figure 2, all of these robotic fingers have joint-like structures commonly known as an 'inelastic element joint drive system'[366]. Tong et al. categorise these into Active Joints, which are traditionally used by robots and are deemed dangerous because they are not attentive and responsive enough to environmental changes, and Passive Joints, which are further divided into three modes: Motor-Driven, Fluid-Driven, and Rope-Driven. These are self-explanatory by their names but are also explained in detail by Tong et al.[367] Motor-driven joints use actuators that connect the flexible elements of the finger. Fluid-driven, also known as pneumatic artificial muscle joints, are actuators driven by compressed air. Rope-driven has its actuator at a point outside the joint connected to the hinge joint, activating a pulley-rope system through it, 'winding and releasing'[368] , which has already been alluded to earlier. Tong et al. state that current systems are inadequate, and one strategy would be to 'integrate multi-sensing information to ensure the effectiveness and safety of task operations.'[369]

[365] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p9.
[366] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p938.
[367] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p938-39.
[368] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p938.
[369] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p940.

In conclusion, the field of SRF presents fascinating ontological questions through its various structural paradigms. The tension between rigid and soft designs, fully actuated versus underactuated systems, and the ongoing challenge of balancing wearability with functionality sit at the heart of current research efforts. While soft SRFs offer greater safety and comfort, and underactuated designs provide lighter weight, these advantages come at the cost of reduced precision and load capacity. The integration of hybrid approaches that combine rigid and soft elements shows promise for addressing these trade-offs.

As this analysis has shown, researchers are increasingly attentive not only to the technical aspects but also aware of the embodied experience of using SRFs, including their psychological impact. Moving forward, the field appears to be evolving toward systems that better integrate multi-sensing information to ensure both effectiveness and safety, potentially bringing us closer to an SRF that can more fully mimic the complex functionality of a biological thumb while maintaining comfortable wearability. The ongoing refinement of these devices represents an important frontier in exploring the relationship between human embodiment and the technics of augmentation.

Control interfaces

To control SRFs, researchers use many types of interfaces. As Shafti et al. explain this topic for us by summarising these interfaces that:

> include inertial measurement units [IMU], […] voice[…], pushbuttons […], and graphical user interfaces […]. Researchers have also explored indirect control interfaces, e.g. using the concept of grasp synergies to assume that the supernumerary robotic finger's posture will be highly correlated with that of natural fingers during manipulation, allowing supernumerary robotic finger control through natural movement of existing fingers. Importantly, all these user interfaces focus on the interface and not the user.[370]

This remark offers a serendipitous insight into how users are often overlooked in this research and the importance of their subjectivity in the design process, an issue central to this thesis. Shafti et al. make other critical remarks, pointing out that researchers frequently fail to focus on what is necessary to meet end-user needs.

Back to the technological control interfaces at hand. Prattichizzo et al. call for a holistic, integrated system of 'proprioceptive and exteroceptive sensors' that allow the 'implementation of algorithms

[370] Ali Shafti et al., "Playing the piano with a robotic third thumb: assessing constraints of human augmentation," *Scientific reports* 11, no. 1 (2021): p2, https://doi.org/10.1038/s41598-021-00376-6.

for the recognition, the prediction, and possibly the autonomous compensation of human motion for enhanced collaboration and safety.'[371] The integrated approach leverages each function's most critically effective modalities, enabling the SRFs to interface with the body in a timely, effective, and responsive manner, thereby enhancing effectiveness. They also say that an SRF with a 'low number of actuated DoFs are usually easier to control from the user point of view, exploiting, for example, wearable switches.'[372] Wearable switches will be discussed later, but for now, we can understand them as switches that help control the SRF, opening and closing it, either controlled by the plantar fascia or, alternatively, by finger via a simple switch. They also highlight the benefits of underactuated devices because of the 'increased compliance of the structure, which can easily adapt to the surfaces touched by the SRL [SRFs], and does not require additional safety features.'[373] Earlier, we discussed that compliance is important for passively adapting to objects with different shapes. We also understand that compliance is crucial to the safety of the wearer and the objects they touch. An example is grasping glass objects without pressure compliance, which can cause glass breakage.

Tong et al. take a different approach by documenting a comprehensive list, which includes SRLs, ten of which are SRFs, as shown in Table 6. Of those listed, most utilise three forms of control. For simplicity, most of the SRFs shown in this table, to which they refer, either use electromyography (EMG)[374], myoelectric interfaces[375] that connect to the residual nerve functions of arm and hand muscle action, or limb mapping technology[376] and push-button interfaces for SRF control. However, their review paper also investigates all the other rather complex control method classification systems used in the broader SRL field, including the emerging technologies that utilise Brain-Machine Interface (BMI) control. I particularly like how Tong et al. classify the control method classifications we referred to above and their use of the label 'control strategy' because these are indeed all strategies, none of which are currently foolproof.

[371] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p10-11.
[372]Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p11.
[373] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," pg11.
[374] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p934-36.
[375] Murat Ayvali, Inge Wickenkamp, and Andrea Ehrmann, "Design, Construction and Tests of a Low-Cost Myoelectric Thumb," *Technologies (Basel)* 9, no. 3 (2021), https://doi.org/10.3390/technologies9030063.
[376] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p934.

Table 6 - Types of support by SRL augmentations and control strategies for SRL augmentations. Taken from Tong et al.[377]

Support by SRL	Synchronous action		√ SRLs and the operator act together in a homogenous or symmetrical manner.
			√ SRLs and the operator play equal roles.
Augmentations	Asymmetric	Passive	√ SRLs play a secondary role, and the user takes a main role.
			√ Main roles include task initiation and exploration or dexterous operation.
		Dynamic	√ SRLs will take the initiative to operate autonomously and play a major role.
			√ SRLs can perform highly complex operations and can be independent of the operator's intention.
	Robot possessed		√ SRLs operate in place of the user.
			√ SRLs replicate or execute human body movements with different scales, displacements or complexity.
Control strategies for SRL	ILCS		√ ILCS are mainly used for repetitive control tasks.
			√ It corrects control amounts at the current time by iterating control errors at the historical time, thereby improving tracking accuracy of the repetitive process.
Augmentations	PVBCS		√ PVBCS can introduce continuous phase variables into the control strategy to solve the problems, where there is no guarantee for the continuity of control amounts.
	AOBCS		√ AOBCS is mainly used to process periodic motion signals.
			√ AOBCS has low requirements for data sources, which has good compatibility with model-based and model-free control strategies.
	Direct control		√ The action of the SRL is completely controlled by the operator (gestures, electromyography, electroencephalography, user interfaces).
	Pseudo-mapping		√ The action of the SRL is generated by the operator's action mapping.
			√ It can be a one-to-one mapping between body positions, or a preset action triggered by the operator's behavior.
	Assisted control		√ The overall actions of the SRL are controlled by the operator.
			√ The robot can play a role in improving accuracy, stability or preventing errors.
	Shared control		√ A master SRL plays a significant role in the control, and it manages the operation of other sub-SRLs related to the task.

Tong et al. build on the work they cite by 'Leigh et al.' and suggest they would improve upon their classification of the 'human-robot-integration problem' by dividing control methods into 'direct control, pseudo-projection control, auxiliary control and shared control according to the degree of autonomy.'[378] The 'Control Method Classification'[379] can be considered the method and type of broad technology and how this strategy and method is deployed into a function. For example, Limb Mapping Control is a control method classification that 'refers to a type of control method that associates the control of an SRL with the wearer's limb movement or limb position to establish a mapping relationship'[380]. Its deployment hinges on the functionality of various strategies that bring about accurate action motion of the SRF. This can be a correction, learning, and relearning strategy, such as the Iterative Learning Control Strategy (ILCS). Limb or hand mapping uses algorithms that predict and control robotic devices based on past limb or hand movements. As Prattichizzo et al. explain, '[t]he control signals are computed without requiring explicit commands by the human user, but interpreting human hand motion.'[381] This includes algorithmic methods such as '[p]artial least square regression [that] is used for predicting a desired posture of the SR Fingers [SRFs] from the

[377] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p937.
[378] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p934.
[379] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p934.
[380] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p934.
[381] Domenico Prattichizzo et al., "An object-based mapping algorithm to control wearable robotic extra-fingers" (2014), p1568.

measurement of human fingers.'[382] Tong et al. cover various other such strategies that I won't explore here. They cite the drawback of such technology, saying, '[a]lthough methods such as limb mapping control are simpler and reliable, they may affect the normal activities of human limbs'[383] in the long term.

Earlier, we cited the use of BMI interfaces as a method for controlling SRFs. Though there is a lot of excitement about BMI interfaces, which can integrate a more holistic experience of both sensing feedback from the environment and neural response systems, Tong et al. point out that 'the control method of BMI is most direct, but is very complicated, and has problems including having a long responsive time, and are prone to misjudgement.'[384] This misjudgement is a derivative of the current technology's limitations in separating the right brain signals from the background noise that is produced and recorded. Tong et al. hold out for the promise that artificial intelligence will resolve some of these inadequacies by bridging the combined multisensory feedback mechanisms and control methods. Meanwhile, as early as 2020, Setiawan et al. from Diponegoro University in Semarang, Indonesia, utilised the latest advancements in neural networks to enhance the efficiency of their SRF by facilitating bi-manual tasks.[385] This means resolving the SRF's motion to respond to the natural use of two hands in unison rather than the fingers of one hand, which is the usual focus of discussion.

Tong et al. delve into a very complex technological territory, which is outside the scope of this dissertation and not particularly useful for our needs. Notably, these complex control systems are broken down into a middle layer (or, alternatively, thought of as an interactive layer between the user and the robotic end-effector), which helps control the level of autonomy and predictability of the SRF or SRL, thereby affecting safety and usability. These systems can be either fully autonomous, semi-autonomous, or hybrid. They are at the heart of the field of human-computer interaction studies, a highly technical field. To put it simply, we need to understand its basic premise. As Tong et al. summarise for us, they propose that:

> [t]he feedback loop in the human-machine system is a key research topic in the design of the augmented system of the available SRLs. It includes important issues such as how to communicate the

[382] Faye Y. Wu and H. Harry Asada, "Implicit and Intuitive Grasp Posture Control for Wearable Robotic Fingers: A Data-Driven Method Using Partial Least Squares," *IEEE transactions on robotics* 32, no. 1 (2016), https://doi.org/10.1109/TRO.2015.2506731.
[383] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p941.
[384] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p941.
[385] Joga Dharma Setiawan et al., "Grasp posture control of wearable extra robotic fingers with flex sensors based on neural network," *Electronics (Basel)* 9, no. 6 (2020), https://doi.org/10.3390/electronics9060905.

> intention of the machine to the user, and how the user can become familiar with the robot's behaviour over time and develop effective communication with the machine.[386]

Tong et al. provide a concise technical table that clearly illustrates the various types of support approaches or technological strategies for the SRL artifact movements and the type of action profile they adopt in SRL (or SRF) augmentation[387] (see Table 6). They further complicate matters by dividing these into more technical categories, which address the control strategies that are involved in controlling the SRL and SRF. Tong et al. suggest that:

> the overall control strategy of SRL system can be divided into three levels: the upper controller (intention recognition), the middle controller (booster planner), and the lower controller.[…] Current research difficulties mainly focus on state data fusion of upper and middle controllers and accurate tracking of lower controllers.[388]

This summary will help us understand that there are many issues in integrating software and control systems, as well as strategies that operate the speed, cadence, and movement vectors of SRFs. The reviewers, Tong et al., also summarise this level of complexity in their block diagram, which illustrates the 'human-robot coupling system'. However, we will not explore this in detail at this point; it is worth noting, as shown in Figure 5. These are generally more applicable to the wider field of SRLs than SRFs; however, they provide a comprehensive structural diagram of how an SRF would work under various control systems. Yang et al., however, adhere to the simpler distinction between control strategies of SRLs and, therefore, translate some of these into control strategies for SRFs. These distinctions break up control strategies into 'Indirect control' and 'Direct control,'[389] which they further subcategorise. We have already given examples of direct control by using switches.

[386] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p938.
[387] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p937. Table III
[388] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p935.
[389] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p631.

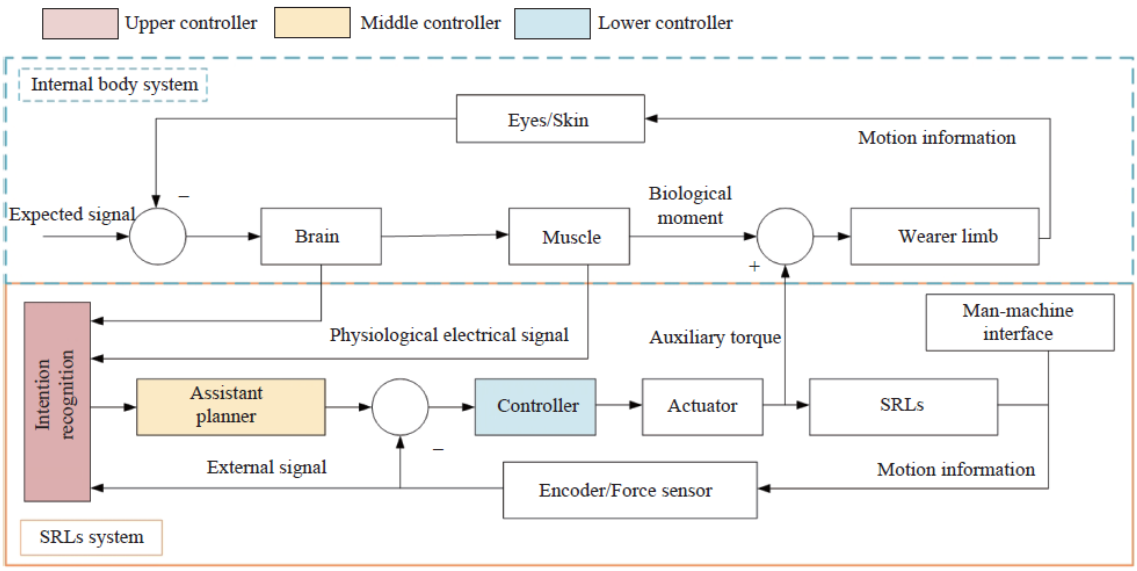

Figure 6 - Block diagram of human-robot coupling system taken from Tong et al.[390]

Firstly, let us go to Yang et al.*'s* explications on Indirect control, which 'generate[s] movements based on human behaviour and coordinate with human actions. Users do not need to send out explicit commands intentionally.'[391] The various indirect control methods can be categorised into two distinct types: 'Demonstration-based control' and 'Balance model-based control'. According to Yang et al., the Demonstration-Based control is a data-driven algorithmic configuration of the SRL or SRF that 'can intuitively transfer intended motions, skills, and strategies to SRLs' and can also be used in SRFs. This data is extracted through various iterations of recorded demonstrations.[392] Similarly, the Balance model-based control utilises human movement data and other data from the SRLs (SRFs) and the environment and objects it interacts with.[393]

As the reader, you may have noticed that, in explaining the various strategies, I have referred widely to SRLs (interchangeably with SRFs, as already indicated earlier in this chapter 1, the Introduction chapter) as the overarching umbrella under which SRFs fall. The reason for referring to SRLs is twofold: firstly, these strategies can be effectively used for SRFs, and some are already partially utilised for controlling SRFs. We see the application of SRL technology applied to SRFs in particular more clearly when referring to Yang et al.'s research, where a summary of Direct Control strategies widely used in SRF paradigms and artifacts will be further examined in this section.

Secondly, turning to Yang et al.'s Direct Control strategies, they regard it as the most common method for control used in many SRFs currently in practice. Yang et al. subcategorise them into:

[390] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p936.
[391] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p631.
[392] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p631.
[393] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p631.

'Manual control', 'Bioelectrical-based control', 'Synergy-based control' and 'Action-based control' according to their catalogue[394] taxonomy. The definitions of these categories are discussed below by Yang et al., breaking the definition into the four above-mentioned groups with given definitions:

> 1) *Manual Control:* The manual control mainly uses buttons or switches to control SRLs and achieve the required operations. This control method is intuitive and effective.[…]
>
> 2) *Bioelectrical_based Control:* Bioelectrical signal-based control is commonly used control method for wearable robots, which mainly uses signals obtained from the human body to control SRLs.[…]
>
> 3) *Synergy-Based Control:* Synergy-based control is inspired and supported by neuroscience studies. These studies have shown that the description of how the human hand performs grasping actions is dominated by postures in a much smaller configuration space than the kinematic structure would suggest.[…]
>
> 4) *Action-Based Control:* Action-based control obtains the user's intention according to the action. The controller generates control rules based on the intention and conveys them to the SRLs.[395]

Yang et al. discuss the advantages and disadvantages of the above systems. They claim that each has certain critical drawbacks and limitations, yet at the same time, they offer a vision for the future due to their advantages. For example, while direct control offers the user predictable, efficient and intuitive control, it also imposes a high cognitive load on the user, which in turn causes fatigue. Other direct control strategies, like EMG, can be of value due to their 'real-time performance'; however, it is challenging to separate and extract complex information about joint and vector actions from the EMG signal because of the high 'signal-to-noise ratio (SNR)'.[396] Other novel concepts from this research include the work by Liu et al., who, in 2022, proposed a 'motor imagery (MI)-based brain-computer interface (BCI) paradigm based on the sixth-finger which [the user] imagines controlling the extra finger movements.'[397]

Reviewers such as Tong et al. mentioned here have employed more technical ontological taxonomies to further categorise the technologies outlined above, but this remains outside the scope.[398] To put it simply, we gain an understanding of the various levels of complexity involved in

[394] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p633-34.
[395] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p633-34.
[396] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p634.
[397] Yuan Liu et al., "EEG characteristic investigation of the sixth-finger motor imagery and optimal channel selection for classification," *Journal of neural engineering* 19, no. 1 (2022), https://doi.org/10.1088/1741-2552/ac49a6.
[398] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p937. Refer to Table III

defining SRF systems and their control interfaces. The categorisations cited by these reviewers provide insight into the complexity of configuring control interfaces and their functions, which are broad and do not necessarily follow a single developmental pathway.

Examining the complex landscape of control interfaces for Supernumerary Robotic Fingers (SRFs), we observe that researchers have developed a diverse array of approaches, ranging from direct control methods utilising switches and buttons to sophisticated indirect systems employing neural networks and brain-machine interfaces. Each control strategy presents distinct advantages and limitations in terms of cognitive load, response time, intuitive use, and adaptability. The technical complexity of these systems reveals multiple ontological layers where human intention must be effectively translated into machine action.

What emerges most clearly from this examination is the tension between technological sophistication and practical usability. Many control systems prioritise technical innovation over end-user needs, overlooking the lived experience of those who might benefit most from these technologies. As control interfaces continue to evolve, the challenge remains to create systems that not only function effectively but also integrate seamlessly with users' embodied experience, acknowledging the importance of subjectivity in human-machine interactions. The development of more intuitive, responsive control interfaces that minimise cognitive load while maximising adaptability will be crucial for the future adoption and acceptance of SRF technologies.

Cognition of SRFs

Our brains appear to be more readily able to cognitively adapt to SRF augmentation than to other forms of SRLs. This is because other SRLs require greater commensurate cognitive capacity than is available. So, for argument's sake, augmenting a finger is easier than augmenting a hand. It is worth exploring the effects and neuropsychology of the Rubber Hand Illusion (RHI) and how it has influenced researchers and philosophers who think about SRF augmentation. This is outside the scope of this dissertation, but worth mentioning. Most of the studies in the field of augmentation that cite the RHI are heavily centred around SRF because the hand has a particular susceptibility to augmentation, as shown by the plethora of Rubber Hand Illusion neurocognitive studies. Most studies have looked at the neurological centres in the brain that control the 'SRF [which] recruits a network of motor-related cortical region'[399] as the natural hands in this illusion using MRI technology.

[399] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p635.

It is also worth taking a moment to explore the terms 'body schema' and 'embodiment', which are introduced to describe how we identify an object, such as the third-thumb, as part of our own body. Again, these are part of a large body of work that falls beyond the scope of this dissertation, but they represent another avenue to explore when trying to understand augmentation. 'Body schema' tends to be the body's experience of itself and its organisation in space, otherwise known as 'motor embodiment'.[400] In contrast, 'embodiment' can refer to a person's image of their body in relation to objects such as SRF. When discussing the distinctions in the use of these terms, I refer to philosopher and psychologist Frédérique de Vignemont, who has done extensive work in this area.[401] Schettler et al. distinguish the relationship between embodiment and body schema in the following way: they posit that the terms are not necessarily exclusive of one another by saying, 'this shows a major difference between perceptual embodiment, which consists in object representation within the body image, and motor embodiment, which consists in object representation within the body schema'[402].

Body schema augmentation and embodiment happen at a neuroscientific and psychological level, respectively. The ability to reinforce these systems in acceptance of a third-thumb means that their wearability, ergonomics and design, as well as their speed, accuracy, strength and feedback systems, are instrumental in reinforcing this artifact as part of one's own body. Yang et al. make some controversial suggestions, citing a research paper 'implying that the use of SRF does not require the acquisition of additional skills or abilities'[403]. This can be true when replacing a lost finger or when there is a loss of hand function—the prosthetic maps onto already established body schemas and sense of embodiment. As we shall see later, the neural resource allocation issues identified as the primary root of the problem provide some evidence to argue against this proposition. However, Yang et al. are persuasive in pointing out that feedback systems enhance the embodiment experience. As they rightly point out, ' [h]ow to adapt and restore the control of natural limbs'[404] after the augmented SRF has been removed remains to be fully evaluated, as it remains unknown how the body reacts neurocognitively when the SRF is removed.

Shikida et al. designed an Extra Robotic Thumb (ERT) (ERT is the prototype's given name to this particular SRF) to experiment and evaluate the level of embodiments the ERT could take. In their

[400] Frédérique de Vignemont, "Embodiment, ownership and disownership," *Consciousness and Cognition* 20, no. 1 (2011/03/01/ 2011): p87, https://doi.org/https://doi.org/10.1016/j.concog.2010.09.004, https://www.sciencedirect.com/science/article/pii/S1053810010001704.
[401] de Vignemont, "Embodiment, ownership and disownership."
[402] Aubrie Schettler, Vicente Raja, and Michael L. Anderson, "The Embodiment of Objects: Review, Analysis, and Future Directions," *Frontiers in neuroscience* 13 (2019): p4, https://doi.org/10.3389/fnins.2019.01332.
[403] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p635.
[404] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p636.

2016 paper, 'Hand Space Change After Use of Extra Robotic Thumb', they conducted two experiments.[405] One measured the difference in hand actions or trajectory using the ERT to see if it persisted after the ERT had been removed. The other was a similar type of experiment in avoiding collision with objects with the ERT on. This assessment also includes measuring persistent perceptual spatial awareness without visual feedback to avoid collisions with objects when the ERT has been removed. The experiments showed an 'anchoring'[406], meaning the ERT is tightly embedded into the body representation after the ERT was detached. The same was found for the second experiment, which showed collision avoidance persisted with a change in ERT posture.[407]

Hussain et al. designed a specific SRF to be compatible with functional magnetic resonance imaging (fMRI) machines, as all other SRFs contain components that produce artifacts (extraneous noise frequencies that appear as anomalies in visual representations) and are therefore incompatible with functioning within that environment.[408] Hussain et al. utilised this SRF to conduct a cognitive and neurological investigation into the impact of the augmentation on the brain's ability to control an extra finger.[409] They note '[o]ne of the major challenge[s] in augmenting the human hand capabilities through supernumerary robotic fingers lies in developing a suitable control interface and in designing algorithms for seamless integration of device motion with that of [the] human hand.'[410] These systems will be discussed further below. Hussain et al. conducted experiments on stroke patients; therefore, they do not clearly define the cognitive impost on those with five healthy fingers. However, their results in stroke patients show that 'the use of supernumerary robotic finger does not require the acquisition of additional skills and abilities.'[411] I would add that this depends on the level of complexity, design, and functionality of the third-thumb, which is not considered in this context. Augmentation for healthy individuals, the core focus of this dissertation, suggests that finding extra neurological resources to contend with new finger functionality is a challenge, which will be explored further in this chapter.

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[405] H. Shikida and Y. Hasegawa, "Hand space change after use of extra robotic thumb" (paper presented at the 2016 International Symposium on Micro-NanoMechatronics and Human Science (MHS), 28-30 Nov. 2016 2016).
[406] Shikida and Hasegawa, "Hand space change after use of extra robotic thumb," p1.
[407] Schettler, Raja, and Anderson, "The Embodiment of Objects: Review, Analysis, and Future Directions," p1332-34.
[408] Irfan Hussain et al., "A magnetic compatible supernumerary robotic finger for functional magnetic resonance imaging (fMRI) acquisitions: Device description and preliminary results" (paper presented at the IEEE Int Conf Rehabil Robot, United States, 2017).
[409] Hussain et al., "A magnetic compatible supernumerary robotic finger for functional magnetic resonance imaging (fMRI) acquisitions: Device description and preliminary results."
[410] Hussain et al., "A magnetic compatible supernumerary robotic finger for functional magnetic resonance imaging (fMRI) acquisitions: Device description and preliminary results," p1179.
[411] Hussain et al., "A magnetic compatible supernumerary robotic finger for functional magnetic resonance imaging (fMRI) acquisitions: Device description and preliminary results," p1181.

Research on SRFs reveals a complex interplay between neurocognitive adaptation, embodiment, and technological design, challenging our understanding of how the human body schema can be augmented. While promising evidence suggests that SRFs can become effectively integrated into our sensorimotor systems, questions remain about the long-term neurological implications and the optimal design parameters to ensure seamless human-robotic augmentation.

Sensing feedback systems

A sensing and feedback system is a crucial characteristic of the current SRF design and a key area of research for successful augmentation. For us to live successfully within our environment, all parts of the body require feedback systems. This has implications for the acceptance of body schema. This is especially true of the hand, which relies on our sense of touch, pressure, and sensation in relation to its environment, and communicates messages to the brain and central nervous system that help predict its actions and reactions. Tong et al. scope this field under a section they call 'sensing and perception systems'.[412] The psychological role of perception is framed as a very important feature in augmentation. It suffices for this dissertation to speak in general terms and say that current sensory systems are in their nascent stages in providing an adequate feedback and response mechanism fast enough for human-computer interaction and that the promise is held out for BMI system integrated with a whole body system that would be the ultimate end solution to this problem, but which are currently too underdeveloped to deal with technical issues that plague its advancement.

Most SRFs that have been developed commonly lack good feedback and sensory systems. Zhu et al. phrase the issue of embodiment as one that is dependent on somatosensory feedback. In their 2019 paper, 'Development of Sense of Self-location Based on Somatosensory Feedback from Finger Tips for Extra Robotic Thumb Control',[413] they outline that the feedback from somatosensory feedback installed in the fingertips of their SRF called extra robotic thumb (ERT), provides an 'update of sense of self-location which is the key aspect of embodiment and contributes to the body representation update, and we [they] elucidate dominant factor which induces the embodiment of an extra robotic thumb (ERT)'.[414] To demystify further terms, Zhu et al. define the sense of self-location as the ability of the body to locate one's body part without visual cues, 'sense of ownership refers to one's self-

[412] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p939.
[413] Yaonan Zhu et al., "Development of sense of self-location based on somatosensory feedback from finger tips for extra robotic thumb control," *ROBOMECH journal* 6, no. 1 (2019), https://doi.org/10.1186/s40648-019-0135-0.
[414] Zhu et al., "Development of sense of self-location based on somatosensory feedback from finger tips for extra robotic thumb control," p1.

attribution of the body, and sense of agency is the sense of having control of motion.'[415] As Liao et al. describe, sensory feedback can be achieved at the fingertips by transmitting 'electrical stimulation signals proportional to the contact force'.[416] Liao et al. preface this by stating that it is challenging to transmit fingertip pressure information to the body and requires a 'multimode feedback via voltage, with an average recognition rate of about 89%.'[417] This means it needs to be in real-time to be effective and have very little latency.

Tong et al.'s 'three components' of sensing and perception systems have simplified the complexity of such systems. They categorise sensors as either 'Mechanical Sensors', 'Physiological Electrical Sensors' or 'Artificial Sensory Feedback Pathways'.[418] The above example, as given by Liao et al., would thus be classified as a physiological electrical sensor under such categorisation.

Mechanical sensors measure the mechanical 'position and velocity'[419] in the SRF and also the torque for measuring joint force. This is usually used in larger SRLs, not in SRFs. Physiological electrical signal sensors provide a means for communication by the wearer using their biological electrical signals, which are usually associated with the 'movement intention of the human body'.[420] The artificial sensory feedback pathway provides a channel for bi-directional movement of sensing and response through artificial feedback, indicating perception and intention. Currently, research is being undertaken in the field of BMI to integrate these systems, which is the most appropriate means of achieving such ambitions.[421,422]

Tong et al. say, 'building a sensory feedback path is a persistent challenge for SRL technology […] Current research can improve accuracy and reduce action time through sensory feedback, so that users can better control SRLs.'[423] As mentioned previously, when discussing control systems, researchers are hopeful that artificial intelligence (AI) will help address some of the challenges associated with combining feedback and control mechanisms in a synchronous loop.[424]

[415] Zhu et al., "Development of sense of self-location based on somatosensory feedback from finger tips for extra robotic thumb control," p2.
[416] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p267.
[417] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p267.
[418] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p393-40.
[419] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p393.
[420] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p393.
[421] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p940.
[422] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p267.
[423] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p940.
[424] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p942.

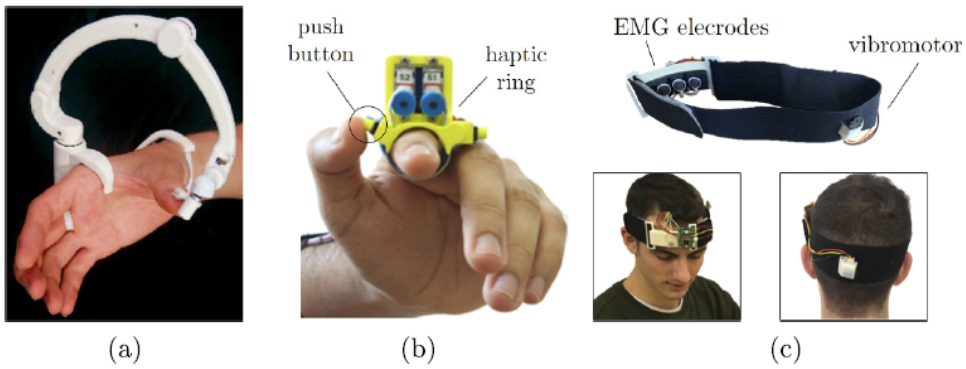

Figure 5. Wearable interfaces for supernumerary robotic fingers. (a) Thumb motion capture device with four encorders: a motion of the right thumb is mapped onto the motion of a supernumerary robotic finger worn on the left hand. © [2015] IEEE. Reprinted, with permission, from [49]. (b) Push buttons embedded in a ring worn on the opposite hand. © [2017] IEEE. Reprinted, with permission, from [55]. (c) EMG headband detecting the activation of the frontalis muscle. © [2019] IEEE. Reprinted, with permission, from [54]. The three interfaces also provide tactile feedback cues: (a) electrical stimulation, (b) vibration and normal forces, (c) vibration.

Figure 7 - Three prototypes with feedback systems taken from Prattichizzo et al.[425]

Prattichizzo et al. consider three SRF devices to be 'exemplary prototypes' of SRFs with feedback systems, as illustrated in Figure 6. They assiduously review other papers and systems, deploying cutting-edge feedback systems. Some use a mobile app, others use switches on other body parts or motion-sensing gloves, while one uses a foot interface to move the SRF. They provide numerous examples of SRFs utilising inertial measurement units (IMUs) to measure the kinetic motion and velocity of hand movements; others employ surface electromyography (sEMG) and EMG-based interfaces. Sometimes, these signals are taken from 'vestigial muscles without predefined functionality'.[426] An example other than the elbow area would be the 'surface electromyograph signals (sEMG) from Auricukalris [sic] muscle located around the ear.'[427] These are examples of what is known as bio-signals.[428] The cognitive advantage of using this type of vestigial manipulation is the engagement of an unused 'communication channel'[429] that will not interfere with the user's normal activities.

When it comes to feeling sensations and getting feedback from the forces of touch at the fingertips, most devices use a haptic system or systems that give 'tactile feedback through an electrical

[425] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p12.
[426] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p13.
[427] Noel Segura Meraz, Hiroshi Shikida, and Yasuhisa Hasegawa, "Auricularis muscles based control interface for robotic extra thumb" (2017), p1.
[428] Leonardo Franco, Gionata Salvietti, and Domenico Prattichizzo, "Command Acknowledge through Tactile Feedback Improves the Usability of an EMG-based Interface for the Frontalis Muscle" (2019).
[429] Meraz, Shikida, and Hasegawa, "Auricularis muscles based control interface for robotic extra thumb," p3.

stimulation'[430] to engage the touch-related force. This means that a voltage is generated proportional to the force of contact.

A commonly referred-to technology cited is a 'wearable cutaneous finger interface' called the hRing[431] or haptic ring, which allows both control and feedback from the environment. Figure 7 shows two motors working across a belt that sits around the finger, which transmits 'both normal and shear forces'.[432] The results from researchers Hussain et al. show that this type of feedback from the environment to the finger 'significantly help[s] to improve the grasping capabilities of paretic hands' and those of healthy hand users.[433]

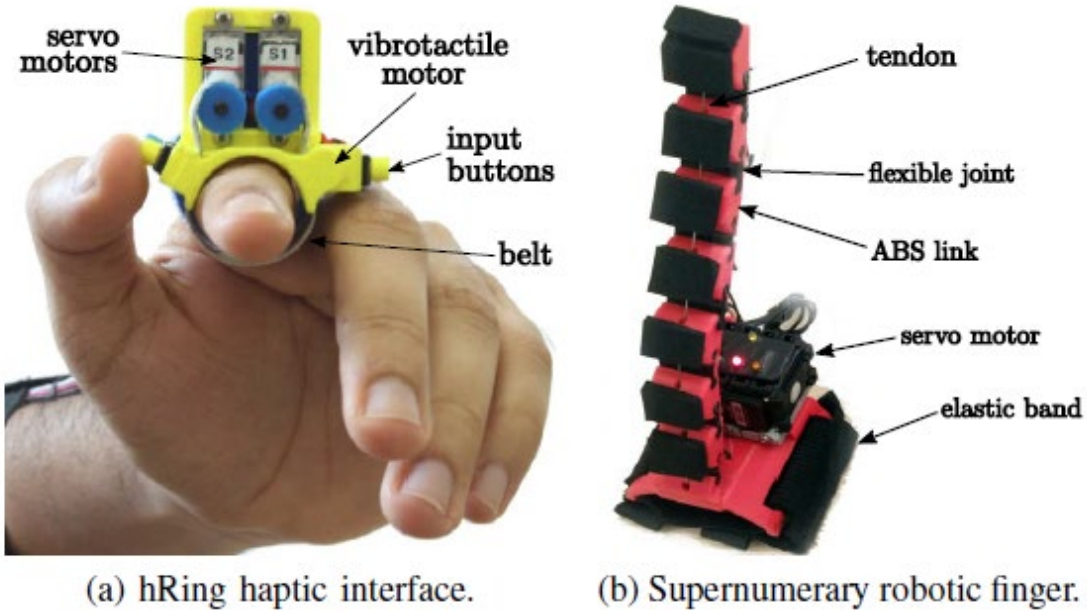

Figure 8 - The hRing and the supernumerary robotic finger. Taken from Hussain et al.[434]

[430] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p14.
[431] Irfan Hussain et al., "A soft robotic supernumerary finger and a wearable cutaneous finger interface to compensate the missing grasping capabilities in chronic stroke patients" (2017), p184.
[432] Hussain et al., "A soft robotic supernumerary finger and a wearable cutaneous finger interface to compensate the missing grasping capabilities in chronic stroke patients," p185.
[433] Hussain et al., "A soft robotic supernumerary finger and a wearable cutaneous finger interface to compensate the missing grasping capabilities in chronic stroke patients," p188.
[434] Hussain et al., "A soft robotic supernumerary finger and a wearable cutaneous finger interface to compensate the missing grasping capabilities in chronic stroke patients," p184.

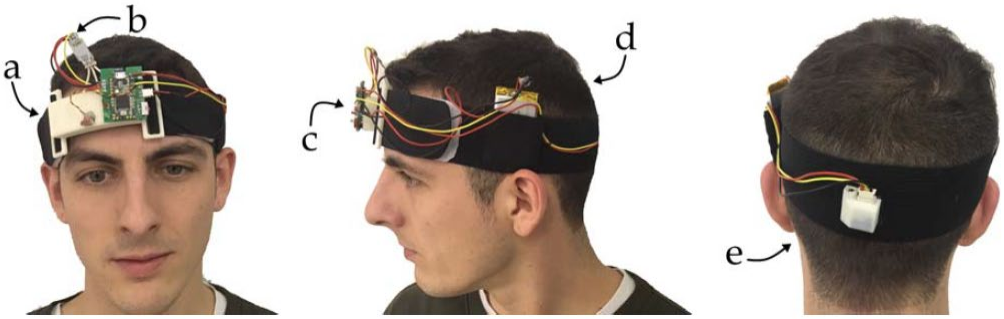

Figure 9 - The Frontalis muscle interface front, side and back view. Arrows indicate: (a), 3D printed electrodes socket with loops for elastic band; (b), EMG conditioning board; (c), sampling and data processing board with Bluetooth module mounted on a custom PCB; (d), Li-Po battery; (e), vibration motor (ERM) for the haptic feedback, embedded in a 3D printed socket, taken from Leonardo et al.[435]

Another popular control mechanism cited in the review below is the eCap.[436] It was developed and extensively used in research papers, especially those in collaboration between Franco Leonardo, Ifran Hussain, Gionata Salvietti and Dominico Prattichizzo.[437] It is a system that continuously informs the user of its intended actions via EMG commands and a feedback loop, as shown in Figure 8. The innovation in this device stems from its use of an electromyography-based (EMG) interface that embeds electrodes in a cap called the eCap, with a vibrotactile motor providing feedback control to the user's awareness that the action is being carried out. Using the EMG control interface, the eCap can detect contractions of the frontalis muscle, which is engaged when moving the eyebrow up or down, depending on whether the SRF is flexing or extending [438] via Bluetooth connection to the SRF.[439] It should be noted here that the frontalis muscle is a muscle of choice used in these experiments because 'it is always spared in case of a motor stroke either of the left or of the right hemisphere due to its bilateral cortical representation and it is usually usable by tetraplegic patients.'[440] To ensure the eCap is carrying out the user's intended action, the vibrotactile feedback improved a visually demanding LED system, which was initially in place. The results showed that the vibrotactile 'haptic feedback enhances the awareness of the user in using the system so that it

[435] Franco, Salvietti, and Prattichizzo, "Command Acknowledge through Tactile Feedback Improves the Usability of an EMG-based Interface for the Frontalis Muscle," Figure 1 - p576.
[436] Franco, Salvietti, and Prattichizzo, "Command Acknowledge through Tactile Feedback Improves the Usability of an EMG-based Interface for the Frontalis Muscle," p574.
[437] Franco, Salvietti, and Prattichizzo, "Command Acknowledge through Tactile Feedback Improves the Usability of an EMG-based Interface for the Frontalis Muscle."
[438] Irfan Hussain et al., "The Soft-SixthFinger: a Wearable EMG Controlled Robotic Extra-Finger for Grasp Compensation in Chronic Stroke Patients," *IEEE robotics and automation letters* 1, no. 2 (2016): p1001, https://doi.org/10.1109/LRA.2016.2530793.
[439] Franco, Salvietti, and Prattichizzo, "Command Acknowledge through Tactile Feedback Improves the Usability of an EMG-based Interface for the Frontalis Muscle," p575.
[440] Franco, Salvietti, and Prattichizzo, "Command Acknowledge through Tactile Feedback Improves the Usability of an EMG-based Interface for the Frontalis Muscle," p574.

becomes faster to execute the task of opening and closing the robotic finger.'[441] It has to be noted that any improvement on this system would include improvements in the 'feedback from the interaction of the device with the environment.'[442] Shikida et al. showed in 2017, two years before the eCaps invention, that researchers discussed the importance of environmental feedback in a paper titled 'Somatosensory Feedback Improves Operability of Extra Robotic Thumb Controlled by Vistigial Muscles'.[443] Shikida et al.'s results demonstrated that '[i]mproved operability indicate[s] a possibility of acquisition of new body representation which is used for motion planning.'[444] They define the body representation as the neurological representation of the body's model, which is stored in the brain.

Somatosensory feedback enhances the efficiency and speed of the SRF, while also improving its accuracy and, consequently, the ease of use for the wearer.[445] Without this, the user becomes over-dependent on the frontalis muscle and may need to move the eyebrow several times or hold it until they receive visual feedback that the SRF is functioning as intended. However, somatosensory feedback is more immediate and is effective in 'reducing muscular effort'.[446] Others have gone further, such as Dowdall et al., whose research suggests that a bidirectional feedback system is crucial for augmentation, 'including both touch and proprioception'.[447] This requirement for touch and proprioception is critical in developing BMI systems, as Amoruso et al. suggest;

> we show that leveraging task-intrinsic somatosensory inputs can substantially enhance motor performance and learning with artificial robotic limbs. By reading motor commands from the cortex and bypassing completely the body, current BMIs may be missing important opportunities for harnessing such task-intrinsic somatosensory signals for motor control.[448]

[441] Franco, Salvietti, and Prattichizzo, "Command Acknowledge through Tactile Feedback Improves the Usability of an EMG-based Interface for the Frontalis Muscle," p578.
[442] Franco, Salvietti, and Prattichizzo, "Command Acknowledge through Tactile Feedback Improves the Usability of an EMG-based Interface for the Frontalis Muscle," p579.
[443] Hiroshi Shikida, Segra-Meraz Noel, and Yasuhisa Hasegawa, "Somatosensory feedback improves operability of extra robotic thumb controlled by vestigial muscles" (2017).
[444] Shikida, Noel, and Hasegawa, "Somatosensory feedback improves operability of extra robotic thumb controlled by vestigial muscles," p4.
[445] Shikida, Noel, and Hasegawa, "Somatosensory feedback improves operability of extra robotic thumb controlled by vestigial muscles," p1,3.
[446] Franco, Salvietti, and Prattichizzo, "Command Acknowledge through Tactile Feedback Improves the Usability of an EMG-based Interface for the Frontalis Muscle," p578.
[447] E. Amoruso et al., "Somatosensory signals from the controllers of an extra robotic finger support motor learning," *bioRxiv* (2021): p13, https://doi.org/10.1101/2021.05.18.444661, http://biorxiv.org/content/early/2021/05/18/2021.05.18.444661.abstract.
[448] Amoruso et al., "Somatosensory signals from the controllers of an extra robotic finger support motor learning," p14.

Based on this exploration of feedback systems for SRFs, it's clear that effective sensory feedback represents both a critical challenge and opportunity in the field. The integration of mechanical sensors, physiological electrical signals, and artificial sensory feedback pathways forms a complex but essential foundation for successful augmentation. Current research demonstrates that bidirectional feedback systems—incorporating somatosensory feedback, haptic mechanisms, and proprioception—significantly enhance performance by improving speed, accuracy, and reducing muscular effort. While technologies like the hRing and eCap represent promising advances, the field continues to move toward more sophisticated Brain-Machine Interfaces (BMIs) that could ultimately provide seamless integration between biological and artificial systems. The future of SRF technology will likely depend on our ability to create feedback mechanisms that effectively update the user's sense of embodiment and body representation, allowing these additional digits to be incorporated into our neurological body model with minimal cognitive load.

Current usability

The rigid ontological structures of SRFs are regarded as unsuitable for longer-term, long-wearing artifacts to augment one's third-thumb as one's own indefinitely. Tong et al. believe that both systems of drives and the structures used in such SRFs may be composed of flexible materials such as pneumatic soft drives and 'novel hydraulic systems that simulate joint flexibility'[449] , thereby increasing usability by reducing weight and touch. Additionally, as previously discussed, there is a need for improved 'intention perception and recognition' and response sensors to be faster, more accurate, and more reactive in such systems, which is a drawback of soft SRFs. However, what seems most important and rarely mentioned is psychological acceptance, which is outside the scope of this dissertation investigation of SRFs and subjectivity. The purely psychological challenge is examined more closely in the cognitive field, but it needs to be considered in greater detail by designers who create SRFs. Tong et al. also reiterate this need in their review.[450] Other issues they identify include the need for systems to have low power consumption and 'high power density of the power supply'[451] to allow 'portability and human mobility'.[452] Tong et al. cite various papers and research to support their findings. They are also the only reviewers examining safety from the perspective of current inadequate standards, as seen in their critical assessment of ISO 13482 standards on safety, for example, in power-assisted robots. Most of the concerns would be more relevant to SRLs with

[449] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p942.
[450] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p944.
[451] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p944.
[452] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p944.

larger spatial footprints and actuators; nevertheless, this is worth noting. For SRFs, risks around safety also apply where there is an issue with the 'conventional high impedance actuators' and if 'power-assisted amplitude will harm the wearer, and whether the system can cope with emergencies correctly'.[453]

Practical applications

Tong et al. have some very interesting visions for the use of SRLs. They promote this technology by detailing the 'broad application prospects in many fields such as national military defence, industrial production, medical rehabilitation, and life services.'[454] In addition to medical rehabilitation, the research reviewed in this dissertation work is based on the premise of satisfying the industrial complex, with the remainder focusing on rehabilitation. Regarding SRF (not SRLs) specifically, we will consider the authors' perspectives on the use of an extra third-thumb and their approach to research throughout the various reviews of the SRF that will be assessed in the following section.

The practical applications for such technology are obvious for those with disabilities, such as stroke patients or those who have lost the use of their finer motor hand skills. As Prattichizzo et al. point out, citing recent research, '[o]ne of the main categories of patients that may benefit from the adoption of supernumerary fingers is that of stroke patients with paretic upper limb.'[455] The reviews discussed in this dissertation validate that numerous medical constraints limit the use of SRFs for rehabilitation. The most applicable scenarios for using SRFs in this area would include 'patients with residual arm mobility' due to the preservation of particular neurological vestiges that allow movements through the activation of residual nerve endings and musculature. This is required for the innervation, activation and control of the SRF. There are many other, more complex medical reasons why there is a current debate around the effectiveness of the therapeutic benefits of SRFs. Prattichizo et al. suggest that the '[r]habilitation with supernumerary robotic fingers is still in its infancy, and comparative trials with traditional approaches have to be implemented.'[456]

On the other hand, using supernumerary fingers in the industrial complex has been unimaginatively seen as having great augmentative benefits for mundane tasks that exploit labour. It is seen as a plus for manipulating objects that usually require two hands, using only one. As Prattichizzo et al. note,

[453] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p944.
[454] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p940.
[455] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p17.
[456] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p18.

'although there is an increasing interest in SRLs, the related research areas is still young and the applicability of these technologies in real-world scenarios is still limited', and that most of the artifacts which they have reviewed 'are prototypes [that] have a quite low technology readiness level (TRL), i.e. TRL<4.'[457] They continue to suggest, however, that some SRFs have higher TRL and are currently being tested with patients in 'activities of daily living (ADLs) by using a supernumerary finger' with a TRL5 to TRL7, which means it has a significant improvement on patient wellbeing. [458] Later in this chapter, we will see numerous projects that are creative, thought-provoking, and push this envelope. For example, the most creative thought on SRFs has led to the design of an SRF specifically for manipulating single chords on the piano. Others have been thoughtlessly invented to feed capitalist greed, focusing on productivity and efficiency on the factory floor. However, this dissertation aims to explore the less practical applications of such augmentative explorations, their impact on the natural human state, and their consequences on life's social and political spheres. Despite the pessimism of some reviewers regarding this broader outlook, Prattichizzo et al. explain that this field of supernumerary robotics, especially SRFs, 'constitutes a technological revolution'[459]. They warn that if the field's progress is not coupled with 'user-centric and iterative' approaches, there is a risk that the opportunities and possibilities for using such technology will remain unexplored.[460]

Earlier, we said that the field of SRLs, specifically SRFs is in its nascent stages. Tong et al. carefully review all the technical challenges that belie the field in detail. In the section of their review under the heading 'Future development trends and challenges'.[461] Tong et al. comprehensively map all the various technical issues and the current status of research at every level of the artifactual SRL. Many of these issues are relevant to SRFs, ranging from the use of soft structures for comfort and wearability to software issues such as mapping motion, predicting limb movement, and feedback sensing routes and responses.[462]

Some of the most interesting aspects of the review papers discussed above are the interceding vision for the research, its value, and foresight. Of the three reviews published in 2021, Prattichizzo et al. have the most interesting discussions that exceed the routine approach taken on SRF

[457] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p18.
[458] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p18.
[459] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," o18.
[460] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p18.
[461] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs."
[462] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p941-44.

development. Their speculation is noteworthy because of the 'perspective' they provide of the future of such projects under the same namesake. Domenico Prattichizzo and Ifran Hussain, authors and contributors to the review, as well as researchers with their own SRF prototypes, are leaders. In 2020, they published a book by Springer under their 'Biosystems & Biorobotics series Volume 26' titled *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*[463] , which compiled most of their own work as well as other prominent projects. They come to the subject area as authorities and thinkers on 'current theoretical and experimental challenges and developments related to the "biomechantronic" design of novel biorobotic machines.'[464] The thoughts presented in this volume of work resonate with the ideas presented in the reviews by Prattichizzo et al*.,* whose outlook into the future advocates the need to look beyond the challenges of researchers dealing with the challenges 'of overcoming technical limitations in the design, sensing, and control of devices' and focusing on unobtrusive systems 'providing the right sensory stimuli to let users feel the SRLs as under their control' as a necessary step for 'sensorimotor augmentation' to move to the next level in progress towards a bodily merger.[465] And this doesn't just include worn devices but also includes those that allow 'motor augmentation (performed by supernumerary limbs) […] [that] can occur *far* from the human body (e.g. with a grounded robot)'.[466] Prattichizzo et al. believe that our ability to succeed in providing a seamless 'bilateral *sensorimotor interface* between the human body (and brain) and the artificial limbs'[467] is critical to the development of the field. They also believe that the future of research must be focused on the 'intuitive and unobtrusiveness of control interfaces […] with the main aim of reducing cognitive burden'[468] upon the user. And they believe the use of haptic feedback,[469] increasing our understanding of the nature of the brain's '"augmentation plasticity"'[470] capacity, and exploiting 'users' musculoskeletal redundancy, i.e. bodily motions and muscle activation that do not affect the main physical interaction with the environment performed by biological hands. This type of thinking is believed to provide breakthroughs to the identified challenges.

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[463] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*.
[464] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, pII.
[465] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p2.
[466] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p19.
[467] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p19.
[468] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p14.
[469] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p14.
[470] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p15.

Prattichizzo et al. justify their position by citing ancient Greek philosophy, 'that humans are the most intelligent of the animals because of their hands',[471] pointing to an argument between Aristotle and Anaxagoras that considers the evolutionary nature of the hand and its relation to human intelligence. The use of SRFs in the field of supernumerary robotics, specially developed for fingers, carries a special kind of paradox not only for the enigmatic nature of the hands' mystique in its relation and its importance to human evolution (as discussed earlier in this chapter on the ideas of the evolutionist John Napier) but also because it involves complex neural integration issues. The integration of augmentative artifacts, such as SRFs, around the awareness of hand space is more easily assimilated, including our readiness to alter perceptions of the hand to shift to new hand models, as seen in the RHI (rubber hand illusion). Pattrichizzio et al. already foresee that in the epoch of artificial intelligence, a significant interplay of biological and computer interactions will resolve some of these challenges 'between bodily intelligence of the human and the artificial intelligence of the SRL.'[472] Whatever the case, these reviews draw our attention to the broader issues of changing hand mapping as we know it biologically and functionally. These ideas further the changing (r)evolutionary possibilities in relation to writing, toolmaking, language and the very basis of social and political structures that have affected our history. Prattichizzo et al. believe that overcoming the technological challenges currently facing the development of SRLs (including all SRFs) discussed above may have implications that are unforeseen within broader social dynamics. However, they remain unclear on those issues, leaving a gap for this dissertation to explore. Therefore, this will form the basis of speculation in later chapters of this dissertation. Pattrichizzio et al. believe it is only a matter of time, given the rapid pace of technological innovation, before progress will be made in this field. That vision extends our current understanding of what they suggest:

> […] neuroscientific implications in the perception of peripersonal space, body representation, sense of agency and, possibly, embodiment when using robotic devices that are physically detached from the user but connected to her/his body through a wearable sensorimotor interface.[473]

Whether the SRF is attached or detached from the body for the purposes of this thesis, the trajectory of the technology isn't the only focus that is in question here, because it is inevitable we shall overcome current technical challenges. Material issues may manifest in other ways, such as

[471] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p18.
[472] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p19.
[473] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p19.

challenging the normative habits of perceiving our bodies and their broader acceptance with augmented artifacts like an SRF, which serves as a ubiquitous extension of our everyday bodies. I would suggest that the augmentation of the robotic third-thumb is on the cusp of being developed into an acceptable techno-biological system. It raises many questions and difficulties in considering the changing nature of our epoch of artificial bodily augmentative evolution.

To explore specific SRF projects, let's examine some particular research projects. It is very challenging to track and classify all the projects. Some projects aim to study the ontologies of one or more fingers, while others investigate dexterity and compare fully actuated systems with underactuated ones. Others examine feedback, and still others are specifically designed to advance neurological studies. Some projects lend themselves better to prosthetics for individuals who have lost the use of a healthy hand, assisting with 'Activities of Daily Living' (ADL). There are also projects aimed at augmenting and extending the mapping of our five fingers to create six or more fingers, or even an extra hand, inspired by some very interesting thoughts. I have thus employed a system of classification to divide the content on SRF projects, following a structure of examination that is roughly circumscribed by the reviewers' work in Yang et al. That is, SRFs are divided into two categories. This has been done because of the simplicity with which they have approached their review as a process. It also cross-references and includes the projects they have missed. Yang et al. divide their list into 'Augmentation of healthy hands capability. Compensation of the dysfunctional hands' capability [and] "Other functions".' They subdivided those categories into 'Wrist-Mounted […] Forearm-Mounted […and] Other Installation Location[s]'.[474] Although the papers reviewed in this dissertation primarily focus on augmenting the ontological structure of prosthetics for a third-thumb to address 'dysfunctional hand capability', they also reveal some interesting directions that may help us understand the use of these artifacts as paradigms for augmenting healthy hands.[475]

Based on the four reviews of supernumerary robotic fingers, it becomes evident that this field sits at a fascinating intersection of technological innovation, philosophical inquiry and corporeal transformation. While the practical applications for rehabilitation and industrial productivity remain the most immediate focus of current research, the deeper implications of altering our fundamental hand structure warrant consideration. The integration of extra digits into our bodily schema raises questions that extend far beyond the technical challenges of design and control interfaces. Indeed, what we are witnessing is potentially a significant evolutionary juncture where the ancient relationship between hand morphology and human cognition enters a new phase. Prattichizzo et

[474] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook."
[475] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook."

al.'s invocation of ancient Greek philosophy regarding the role of the hand in human intelligence effectively underscores this point. As we continue to develop these technologies, we must remain attentive not only to solving material constraints but also to understanding how these augmentations might reshape our perceptions of embodiment, our social structures, and even our political frameworks, which the capabilities of the human hand have historically influenced. The supernumerary robotic finger thus represents not merely a technical innovation, but a philosophical inflection point in our understanding of what constitutes the human body and its boundaries.

Review of individual SRF projects split into two categories

The vision for researchers is the functional addition of one or more fingers, enabling a single hand to achieve the dexterity necessary to accomplish tasks that would normally require two hands, or even to perform tasks impossible with two natural hands. The exploration of the following projects aims to demonstrate the various interesting characteristics associated with creating a useful SRF that surpasses mere technical advancements. Here, we are looking for the underlying lines of enquiry that will open the discussion to ideas, creativity, motivations, affect, and modes of enquiry. Most of all, it examines possible threads of connection between the subjectivity of the creator and the user. To distinguish between the various prototypes created, it was easiest to divide the SRFs into wrist-mounted and forearm-mounted devices (reasons explained in the previous section), as this has been the most effective taxonomic system also employed by Yang et al., as discussed earlier. The projects are presented chronologically, from the oldest to the most recent.

Wrist-mounted

Most of the prominent reviewers cited Prattichizzo et al.[476] extensively. Domenico Prattichizzo, Professor of Robotics at the University of Siena, has introduced the 'Robotic Sixth Finger, a modular, rigid, fully actuated device.'[477]

[476] D. Prattichizzo et al., "The Sixth-Finger: A modular extra-finger to enhance human hand capabilities" (paper presented at the The 23rd IEEE International Symposium on Robot and Human Interactive Communication, 25-29 Aug. 2014 2014).
[477] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p6.

Figure 10 - Prattichizzo's first prototype of the Sixth-Finger, taken from Prattichizzo et al.[478]

Figure 9 shows the first iteration of the prototype of the Sixth-Finger. They concisely describe in their abstract that this paradigm was specifically designed as:

> an extra-limb in order to enhance manipulation dexterity and enlarge the workspace of human beings. In this work, the model and control of an additional finger, the Sixth-Finger, is presented as a case study of this type of robotic limb. The robotic finger has been placed on the wrist opposite to the hand palm. This solution allows to enlarge the hand workspace, increasing the grasp capability of the user. An object-based mapping algorithm is proposed to control the robotic extra-finger by interpreting the whole hand motion in grasping action. […] The proposed Sixth-finger can lead to a wide range of applications in the direction of augmenting human capabilities through wearable robotics.[479]

This Sixth-Finger or SRF has four degrees of freedom (DoF) for flexion and extension motion and one DoF for 'abduction/adduction'.[480] Prattichizzo et al. indicate that the finger has both 'proprioceptive sensors (encoders in the joints)' and that in a later work by Hussain et al., who built upon this SRF, they improve the Sixth-Finger. Hussain et al. propose that their Sixth-Finger 'has been enriched with

[478] Prattichizzo et al., "The Sixth-Finger: A modular extra-finger to enhance human hand capabilities," p993.
[479] Prattichizzo et al., "The Sixth-Finger: A modular extra-finger to enhance human hand capabilities," p993.
[480] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p6.

force-sensing resistors placed on the finger's phalanges to allow for a more precise control by the humans.'[481] Through a 'switch placed on the ring, while being provided with vibrotactile feedback about the forces exerted by the robotic finger on the environment', the user can control the motion of the robotic finger, as seen in Figure 7.[482] According to Yang et al., this innovation of the a Sixth-Finger or third-thumb shows that the:

> users can successfully complete *anatomically impossible* grasps and *ulnar* grasps. The anatomically impossible grasp refers to grasping objects which cannot be grasped using only one hand. The ulnar grasp means that a hand can accomplish two actions simultaneously, e.g., grasping a bottle with the ring finger, little finger, and SRF, while the other fingers perform opening the bottle cap.[483]

As mentioned, the prototype of the Robotic Sixth-Finger, first developed and published in 2014, was developed by Prattichizzo et al. In their paper, the researchers stopped short of envisioning the real social and political implications of such ground-breaking work. They limited themselves to concluding with an underwhelming comment, saying that the prototype had 'interesting applications in human-robot interaction and in particular in wearable robotics,' which is not an insightful vision for the real implications of their work.

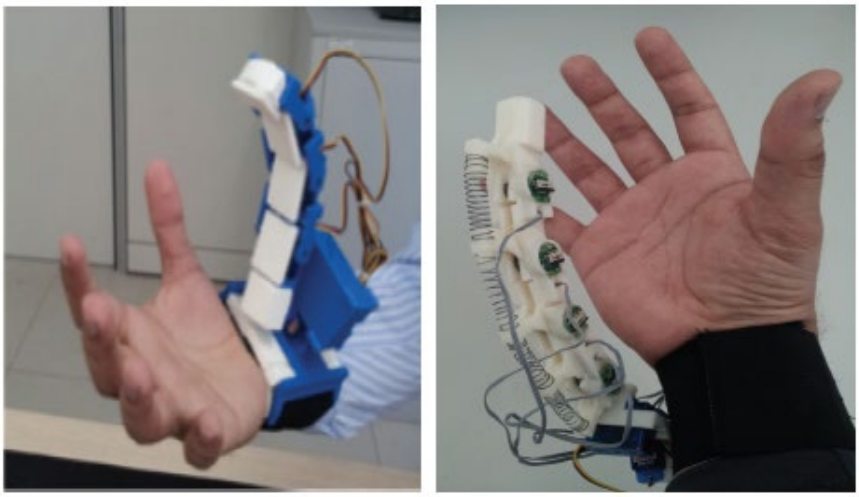


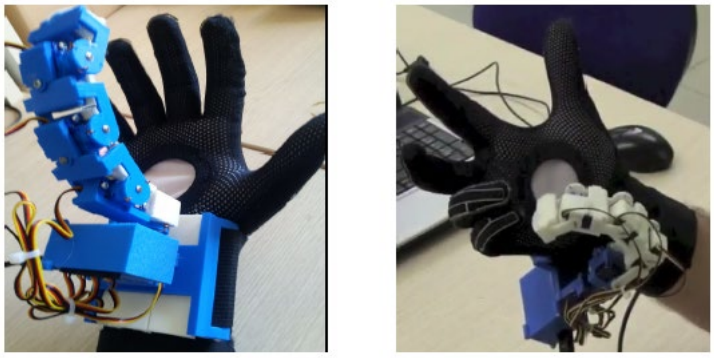
Figure 11 -The robotic extra finger prototypes. The fingers are embedded in a bracelet that can be worn on the wrist. When the robotic finger is not necessary, it wraps up on the wrist. When activated, it interacts with the human fingers in grasping and manipulation tasks. Taken from Hussain et al.[484]

[481] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p6.
[482] Irfan Hussain et al., "Vibrotactile haptic feedback for intuitive control of robotic extra fingers" (2015), p394.
[483] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p625.
[484] I. Hussain et al., "Design guidelines for a wearable robotic extra-finger" (paper presented at the 2015 IEEE 1st International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI), 16-18 Sept. 2015 2015), pg 54, Figure 1.

A close collaborator of Professor Prattichizzo and a highly published scholar is Irfan Hussain, Assistant Professor at Khalifa University, who followed up on the above research in 2015 by publishing a paper called 'Design Guidelines for a Wearable Robotic Extra-Finger'.[485] Hussain et al. use a similar-looking artifact to Prattichizzo's Sixth-Finger as seen in Figure 10, except '[t]hey utililized different placement positions called central configuration [placing the thumb central to the palm] and second thumb configuration and reduced the number of motors creating an underactuated version of the Robotic Sixth-Finger'[486]. Ifran Hussain et al. describe it in the following ways:

> In the *central* configuration, the finger is placed in the center of the wrist, opposite to the four fingers of the human hands so to enlarge the hand workspace. […] In the *second thumb* configuration [where a third thumb is added], the aim is to provide an additional thumb to the hand, placed next to the pinkie finger.[487]

This is shown in Figure 11.



(a) Central configuration. (b) Second thumb configuration.

Figure 12 - The robotic extra finger in two possible configurations on the wrist. Taken from Hussain et al.[488]

Although Prattichizzo et al. and Hussain et al. produced two fully developed models, the actuated and underactuated versions, due to its passively underactuated compliant structure, the underactuated finger can adapt to the shape of the grasping objects more easily.[489] [490] Underactuation is one of the strategies discussed earlier to reduce the weight of the SRF and increase its shape compliance for environmental objects. Hussain et al. also added the vibrotactile

[485] Hussain et al., "Design guidelines for a wearable robotic extra-finger."
[486] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p6.
[487] Hussain et al., "Design guidelines for a wearable robotic extra-finger," p56.
[488] Hussain et al., "Design guidelines for a wearable robotic extra-finger," pg56, Figure 4.
[489] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p625.
[490] Hussain et al., "Design guidelines for a wearable robotic extra-finger," p56.

interface[491] to increase the user's response level. They say that the '[h]uman hand together with this SRF can perform six complex tasks, including unscrewing a cap of the bottle, grasping a bigger box, grasping two balls, opening the door, soldering a board, and grasping a plate and a glass.'[492] What is strikingly interesting is that this work was developed using 'rapid prototyping techniques'[493] that took advantage of 3D printing technology more than a decade ago. Design guidelines, such as those developed by Hussain et al., provide pathways for the ease of invention and production of SRFs that can be completed at home in a matter of hours. This type of research provides the stepping stones for future ubiquity in the production and customisation of augmented hand artifacts or SRFs. These prototypes neatly 'wraps up on the wrist as a bracelet when it is not used and it pops-up when it is actuated'.[494]

Between 2014 and 2015, a series of papers featuring a wrist-mounted device called the Supernumerary Robotic Finger (SR) was published by Wu and Asada[495] [496]. The SR had 'two SR Fingers [that] are attached to the human wrist to form a 7-fingered hand.'[497] By using 'postural synergies among the seven fingers, '[498] Wu and Asada developed an algorithm they named '"Bio-artificial"'[499] to differentiate it from the traditionally neurophysiologically EMG-inspired control systems. This system allows the SR to have multiple DOFs that are easier to control and function. They further this work through the addition of 'tactile sensors'[500] to more effectively grasp irregular and geometrically oddly shaped objects.

[491] Hussain et al., "Vibrotactile haptic feedback for intuitive control of robotic extra fingers."
[492] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p625.
[493] Hussain et al., "Design guidelines for a wearable robotic extra-finger," p54.
[494] Hussain et al., "Design guidelines for a wearable robotic extra-finger," p56.
[495] Faye Wu and Harry Asada, "Bio-Artificial Synergies for Grasp Posture Control of Supernumerary Robotic Fingers," (07/22 2014), https://doi.org/10.15607/RSS.2014.X.027.
[496] Faye Wu and Harry Asada, "Supernumerary Robotic Fingers: An Alternative Upper-Limb Prosthesis," *ASME 2014 Dynamic Systems and Control Conference, DSCC 2014* 2 (10/22 2014), https://doi.org/10.1115/DSCC2014-6017.
[497] Wu and Asada, "Bio-Artificial Synergies for Grasp Posture Control of Supernumerary Robotic Fingers," p2.
[498] Wu and Asada, "Bio-Artificial Synergies for Grasp Posture Control of Supernumerary Robotic Fingers," p2.
[499] Wu and Asada, "Bio-Artificial Synergies for Grasp Posture Control of Supernumerary Robotic Fingers," p2.
[500] Wu and Asada, "Supernumerary Robotic Fingers: An Alternative Upper-Limb Prosthesis," p7.

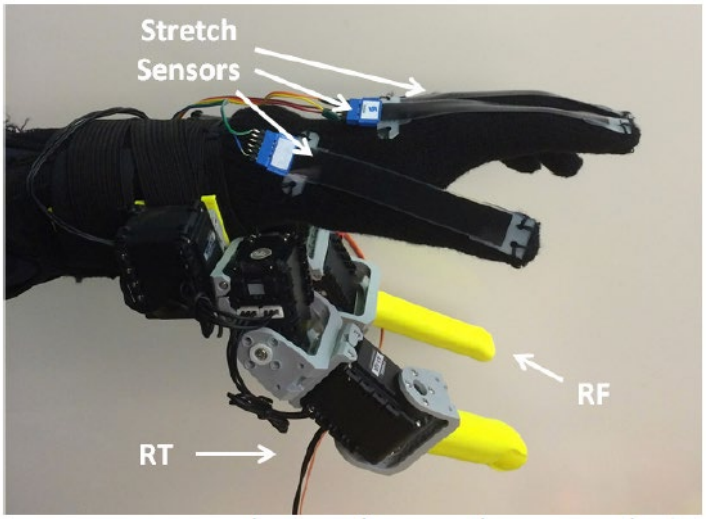


Figure 13 - The SR fingers are mounted on the human wrist to form a 7-fingered hand: 5 Human fingers and two robotic fingers (a Robotic Thumb (RT) and Robotic Finger (RF)). Using only three stretch sensors, the motion of the SR Fingers can be coordinated with that of the human fingers, as described in Wu et al.[501]

As seen in Figure 12, Wu and Asada distinguish the two artificial fingers by mapping the RT (Robotic Thumb) as 'moving similarly to the human thumb' and the other RF (Robotic Finger) mapped to the motions of 'the long fingers'.[502] The SR they developed does not look like traditional fingers or thumbs. Instead, it is open to various sizes, ranges, and motions that would usually be limited by the human hand if it were offered with naturally sized fingers. Wu and Asada justify this design by pointing out the benefits of such a morphology as being 'especially beneficial for grasping objects that are usually deemed difficult to grip, including objects that are large, oddly-shaped, heavy, slippery, too hot, or too cold. […] Additionally, tools can be attached to the SR Fingers to facilitate tasks that require more than the bare hands',[503] as seen in Figure 13.

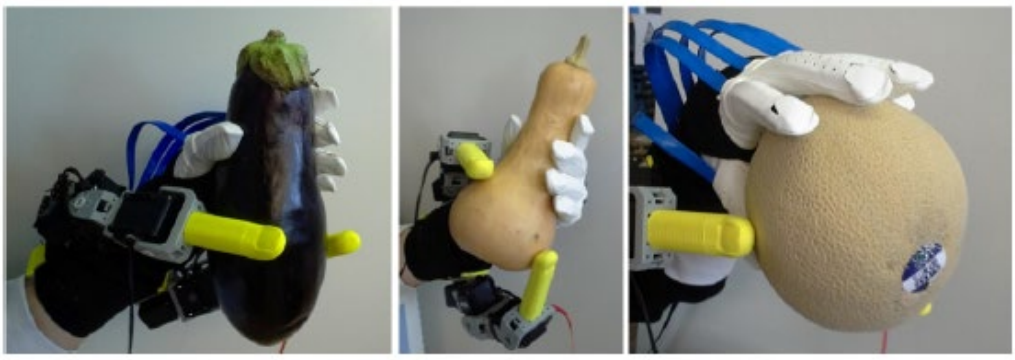


Figure 14 - Oddly shaped objects held by one hand, as demonstrated using the SR fingers, were taken from Wu et al.[504]

[501] Wu and Asada, "Supernumerary Robotic Fingers: An Alternative Upper-Limb Prosthesis," p7.
[502] Wu and Asada, "Bio-Artificial Synergies for Grasp Posture Control of Supernumerary Robotic Fingers," p2.
[503] Wu and Asada, "Supernumerary Robotic Fingers: An Alternative Upper-Limb Prosthesis," p2.
[504] Wu and Asada, "Supernumerary Robotic Fingers: An Alternative Upper-Limb Prosthesis," p6.

Similar to other researchers, the short-sightedness and brevity of Wu and Asada's vision regarding the potential of its use are a little disheartening. They vacillate between saying the SR Fingers, which will enhance 'the capability of senior citizens and people with disabilities, allowing them to enjoy a greater sense of independence or get employment opportunities that were otherwise not available to them.'[505] While they also say SR Fingers are most useful 'in diverse tasks and contexts, such as manufacturing, construction, and elderly care. SR limbs will be a promising and important branch of wearable robots that will infuse unique concepts of human-robot coordination'.[506] They stop short of explaining their vision and do not specify how they envision the ramifications of such a capability within the broader context of acceptance and social change. The lack of ideas with broader implications does not seem to fall within the purview of science or engineering. Still, it should at least have some commentary that opens up and shows that the research does not exist *ex nihilo*.

Before returning to Wu and Asada and their other research, we need to mention Leigh et al., who in 2016 utilised the concept of hand synergy mapping in a novel way. They utilise it as a design epistemology to create a 'wearable multi-joint interface that offers "synergetic interactions" by providing additional fingers, structural supports, and a physical user interface.'[507]

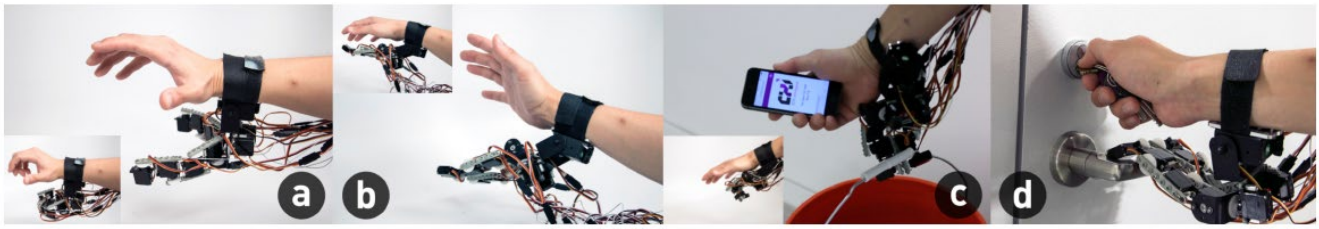


Figure 15 -Different configurations for our device. a) A gripper on the wrist, b) another palm to pick up big objects, c) a hook inside the hand, and d) robotic joints working in tandem, unlocking a door (the hand turns the key, and the joints rotate the knob). Taken from Leigh et al.[508]

As seen in Figure 14, Leigh et al.'s SRF has a varied reconfigurability of permitting various states of design to emerge: a gripper, or a palm, a hook inside a hand, 'a robotic joint working in tandem unlocking a door' while turning the key, a joystick, a trigger interface, a holding device and more.[509] This system uses EMG signals picked up from the elbow joint or the brachioradialis muscles, which

[505] Wu and Asada, "Supernumerary Robotic Fingers: An Alternative Upper-Limb Prosthesis," p7.
[506] Wu and Asada, "Bio-Artificial Synergies for Grasp Posture Control of Supernumerary Robotic Fingers," p8.
[507] Sang-won Leigh and Pattie Maes, "Body Integrated Programmable Joints Interface" (Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, San Jose, California, USA, Association for Computing Machinery, 2016).
[508] Leigh and Maes, "Short Body Integrated Programmable Joints Interface." p6053 Figure 1.
[509] Leigh and Maes, "Short Body Integrated Programmable Joints Interface." p6053.

helps coordinate programs like its Gesture Recognition Toolkit, which gives it 'context-awareness'.[510] The authors are inspired by Stelacs 'trans-humanistic idea of having additional limbs' and Heidegger's varying perception of tool usage.[511] But they stress that they strive to design an artifact that does not hinder our natural 'kinesthetic skills' when not in use, 'providing augmentation only when they are needed rather than enforcing the continuous use of them.'[512] As we shall see later, Sang-won Leigh will go on to develop other toolkits to try to make SRFs more ubiquitous.

In 2015, to resolve grasping issues found in previous tests in their research, Wu and Asada set about designing a new version of the SR Finger prototype in their paper '"Hold-and-Manipulate" with a Single Hand Being Assisted by Wearable Extra Finger'.[513]

Figure 16 -The new SR Finger Prototype contains 4 DOF, including servo-actuated abduction and cable-driven flexion, taken from Wu et al.[514]

As seen in Figure 15, the SR finger 'adapts to geometric irregularities and material uncertainties and can grasp and hold a multitude of objects.'[515] These tasks include 'twisting off the cap of a water bottle, opening the lid of a food container, plugging a cable into an electronic device and mixing salad in a bowl.'[516] A unique feature of this multi-functional hand robot is its prehensile dynamics, which utilises aspects of natural muscular biology to innervate its movements. Two of its control

[510] Leigh and Maes, "Short Body Integrated Programmable Joints Interface." p6055.
[511] Leigh and Maes, "Short Body Integrated Programmable Joints Interface." p6056.
[512] Leigh and Maes, "Short Body Integrated Programmable Joints Interface." p6056.
[513] F. Y. Wu and H. H. Asada, ""Hold-and-manipulate" with a single hand being assisted by wearable extra fingers" (paper presented at the 2015 IEEE International Conference on Robotics and Automation (ICRA), 26-30 May 2015 2015).
[514] Wu and Asada, ""Hold-and-manipulate" with a single hand being assisted by wearable extra fingers," pg 6207 Figure 2.
[515] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p625.
[516] Wu and Asada, ""Hold-and-manipulate" with a single hand being assisted by wearable extra fingers," p6205.

protocols use the redundancies in the human arm musculature to link it to human-robot motions[517], using 'movement in the elbow, in addition to grasp synergy [discussed earlier] to achieve SR Finger assisted '"hold-and-manipulation."'[518] They also propose improving their SR Finger with finger motion sensors, force output sensors, and haptic feedback in the skin to better control and communicate with the SR Finger.[519]

In 2016-2018, Ifran Hussain and a group of researchers, which included the notable Domenico Prattichizzo and Gionata Salvietti, introduced a series of papers using the Soft-Sixth Finger[520,521,522]. In their paper 'The Soft-Sixth Finger: A Wearable EMG Controlled Robotic Extra-Finger for Grasp Compensation in Chronic Stroke Patients', they propose a device that 'can be wrapped around the wrist and worn as a bracelet when not used.'[523] This was based on an earlier version by Domenico Prattichizzo and Ifran Hussain.

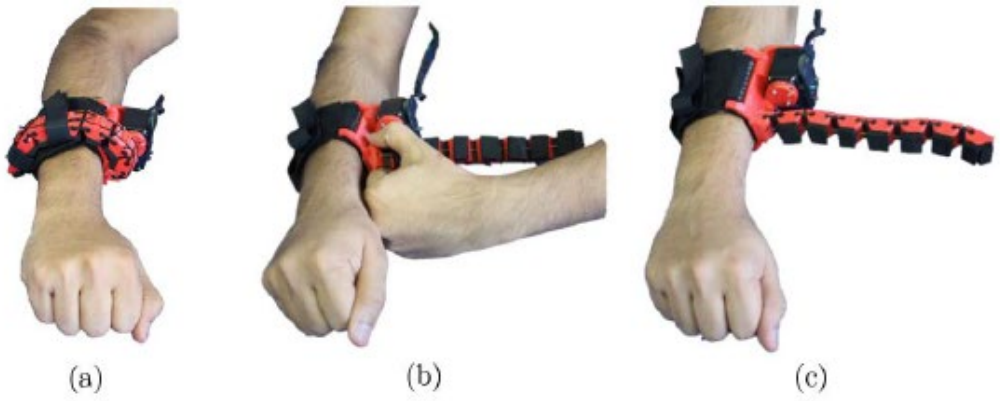


Figure 17 - From rest to working position. (a) The Soft-Sixth Finger is worn as a bracelet in its resting position. (b) The patient can use their healthy hand to rotate the robotic finger. (c) The Soft-Sixth Finger in its working position.Taken from Hussain et al.[524]

[517] Wu and Asada, ""Hold-and-manipulate" with a single hand being assisted by wearable extra fingers," p6206.
[518] Wu and Asada, ""Hold-and-manipulate" with a single hand being assisted by wearable extra fingers," p6208.
[519] Wu and Asada, ""Hold-and-manipulate" with a single hand being assisted by wearable extra fingers," p6211.
[520] Hussain et al., "The Soft-SixthFinger: a Wearable EMG Controlled Robotic Extra-Finger for Grasp Compensation in Chronic Stroke Patients."
[521] Irfan Hussain et al., "A soft supernumerary robotic finger and mobile arm support for grasping compensation and hemiparetic upper limb rehabilitation," *Robotics and autonomous systems* 93 (2017), https://doi.org/10.1016/j.robot.2017.03.015.
[522] Irfan Hussain et al., "An EMG interface for the control of motion and compliance of a supernumerary robotic finger," *Frontiers in neurorobotics* 10 (2016), https://doi.org/10.3389/fnbot.2016.00018.
[523] Hussain et al., "The Soft-SixthFinger: a Wearable EMG Controlled Robotic Extra-Finger for Grasp Compensation in Chronic Stroke Patients," p1000.
[524] Hussain et al., "The Soft-SixthFinger: a Wearable EMG Controlled Robotic Extra-Finger for Grasp Compensation in Chronic Stroke Patients," pg1002 Figure 3.

The Sixth Finger was updated in 2015 for 'stroke patients to compensate for the missing hand functions of the paretic limb.'[525] Unlike The Sixth Finger, which is controlled via a vibrotactile ring, the newest version of the finger-like extension seen in Figure 16 can be worn and adjusted around the forearm, above the wrist, and is adjustable in response to a wider variety of motor deficits in patients with a paretic hand. It can be worn on the 'distal part of the forearm (near the wrist), so to obtain the grasp by opposing the device to the paretic hand.' Or it can be 'positioned more proximal at the forearm, so to let the grasp be achieved by the extra-finger opposition to the radial part of the wrist.'[526] The innovation in this device is evident in its use of an electromyography-based (EMG) interface, which embeds electrodes in the cap called the eCap (discussed earlier in this chapter), allowing it to control the finger. Using the EMG control interface, the eCap can detect contractions of the frontalis muscle, which is engaged when moving the eyebrow[527]. This also uses passive underactuated technology to make gripping more compliant with objects. As Hussain et al. explain:

> [t]he main contribution of this work is the development of a novel EMG interface that can be used to control both the motion of the supernumerary robotic finger and its compliance and thus the tightness of the obtained object grasp. In particular, we relate different finger motions to different gestures of the human hand.[528]

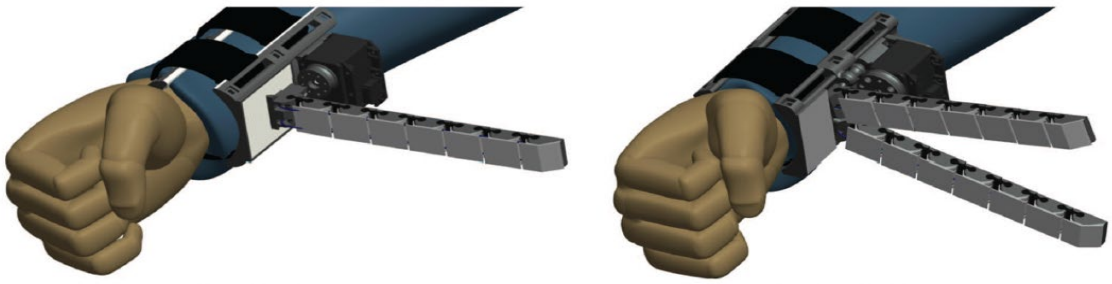


Figure 18 - Proposed wearable robotic compensatory devices for the hemiparetic upper limb. Left: A single extra finger is proposed to compensate for the missing hand-grasping function. Right: A double-finger design is proposed to enhance grasp stability and payload, as described in Hussain et al.[529]

[525] Irfan Hussain et al., "Using the robotic sixth finger and vibrotactile feedback for grasp compensation in chronic stroke patients" (2015), p67.
[526] Hussain et al., "The Soft-SixthFinger: a Wearable EMG Controlled Robotic Extra-Finger for Grasp Compensation in Chronic Stroke Patients," p1002.
[527] Hussain et al., "The Soft-SixthFinger: a Wearable EMG Controlled Robotic Extra-Finger for Grasp Compensation in Chronic Stroke Patients," p1001.
[528] Hussain et al., "An EMG interface for the control of motion and compliance of a supernumerary robotic finger," p2.
[529] Irfan Hussain et al., "Toward wearable supernumerary robotic fingers to compensate missing grasping abilities in hemiparetic upper limb," *The International journal of robotics research* 36, no. 13-14 (2017): p1417 Figure 1, https://doi.org/10.1177/0278364917712433.

Later in 2016, Hussain et al. doubled the number of fingers of the Soft-Sixth Fingers into two Soft-Sixth Fingers, otherwise called 'the double soft sixth finger'[530], as seen in Figure 17. This will be explored later as it is not strictly a wrist-worn device but an arm-worn device that falls under the forearm-mounted SRFs discussed in the next section.

As with the improved Sixth Finger discussed above, the idea of a device that can be worn in different positions around the human wrist was the driving theme for Leigh et al., who, between 2017 and 2018, designed the Morphology Extension Kit (a kit to make customisable modular SRFs).[531] Moreover, the researchers went above and beyond to innovate a 'robotic platform for customisable physically capable wearables […] to build and customise physical augmentations.'[532] Their innovation provided a flexible 'modular robotic assembly kit'[533] for easy modifications to supplement additional electronics based on the need or desire for particular sensing capabilities. This would be done on demand using standardised modules and segments that clasp together easily, while 'there is no effort required from the user other than simply plugging the modules together.'[534]

In another paper in 2017, Sang-won Leigh collaborated with Yuhan Hu, and they developed a paper titled the 'Hand Development Kit: Soft Robotic Fingers as Prosthetic Augmentation of the Hand'[535].

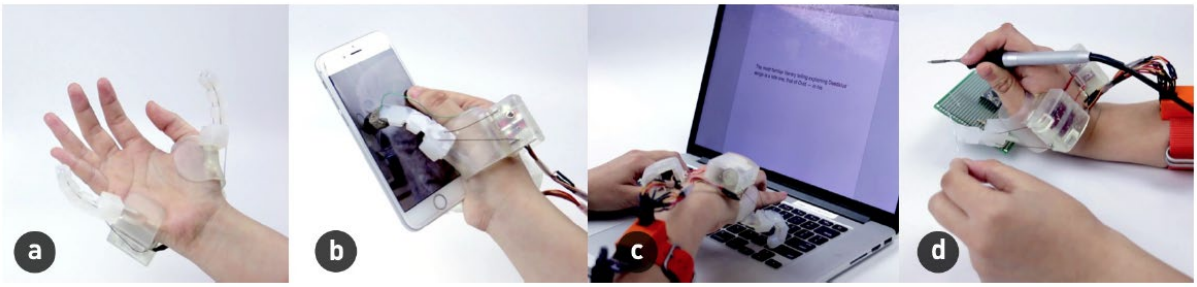


Figure 19 - a) The configuration of our system. b) performing a multi-touch gesture with the soft robotic finger. c) The soft robotic finger supports keyboard typing. d) The fingers can hold and adjust the position of an object in tri-manual tasks. Taken from Leigh et al.[536]

[530] Hussain et al., "Toward wearable supernumerary robotic fingers to compensate missing grasping abilities in hemiparetic upper limb," p3.
[531] Sang-won Leigh et al., "Morphology Extension Kit: A Modular Robotic Platform for Customizable and Physically Capable Wearables" (paper presented at the Conference on Human Factors in Computing Systems, 2017).
[532] Leigh et al., "Morphology Extension Kit: A Modular Robotic Platform for Customizable and Physically Capable Wearables," p397.
[533] Leigh et al., "Morphology Extension Kit: A Modular Robotic Platform for Customizable and Physically Capable Wearables," p398.
[534] Leigh et al., "Morphology Extension Kit: A Modular Robotic Platform for Customizable and Physically Capable Wearables," p399.
[535] Yuhan Hu, Sang-Won Leigh, and Pattie Maes, "Hand development kit: Soft robotic fingers as prosthetic augmentation of the hand" (2017).
[536] Hu, Leigh, and Maes, "Hand development kit: Soft robotic fingers as prosthetic augmentation of the hand," p27 Figure 1.

As seen in Figure 18, their Soft Robotic Fingers consist of two opposable fingers, an extra thumb that clasps onto the belly of the existing thumb and another pinky that sits next to the palm near the natural pinky. Their innovations include this uncanny ability to modularise and rapidly prototype the components, allowing the SRFs to be customised and manufactured on non-commercial premises. They produce soft robotic fingers that are lightweight and highly compliant with objects. Their concept utilises smartphones as an interface to control the SRF artifact. Although they propose this as an augmentative device for healthy hands, they also position it for individuals with disabilities due to its ease of configurability. They say, '[o]nce a finger with a different size or motion is needed, one can simply fabricate a new soft robotic finger with the desired properties and replace the ones no longer needed'[537] using their kit model.

In 2018, an ambitious project moved to stake its claim to purely and imaginatively augment the healthy hands of a capable human with ten working fingers with a robotic one; 'to serve as a test ring for human augmentation through wearable robotics, allowing research into questions on embodiment and learnability of their use'[538]. Cunningham et al. presented this to us in their Robotic 3rd Thumb[539] (SR3T) project. They wanted to challenge the possibility of the 'eventual cognitive embodiment, allowing the user to adapt to them [the SR3T] and use them seamlessly'[540]. They go on to illustrate that their 'supernumerary robotic 3rd Thumb was created to augment piano playing, allowing a pianist to press piano keys beyond their natural hand-span; thus leading to functional augmentation of their skills and technical feasibility to play with 11 fingers.'[541]

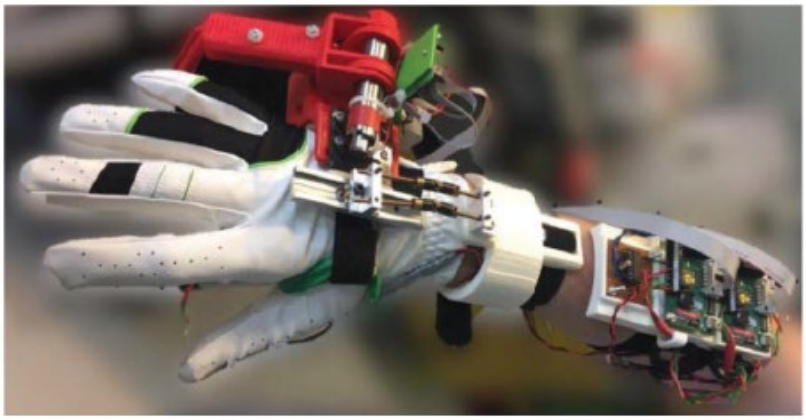


Figure 20 - supernumerary robotic 3rd thumb (SR3T), taken from Cunningham et al.[542]

[537] Hu, Leigh, and Maes, "Hand development kit: Soft robotic fingers as prosthetic augmentation of the hand," p28.
[538] James Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks" (2018), p666.
[539] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks."
[540] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p665.
[541] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p665.
[542] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p665 Figure 1.

As seen in Figure 19, this is a fully rigid robotic finger with only two DoF, one for vertical and one for horizontal motion.[543] This project deals with the finer functions of 'applying forces and variable force exertion in functional tasks.'[544] Thus, the robotic finger was designed to mimic and model 'an average adult male's middle finger dimensions.'[545] It resulted in a resounding success, with the researchers claiming users could 'learn and control the SR3T quickly, and was able to produce musical results in hours which is little time compared to rehabilitation times for bionic prosthetics users of months.'[546]

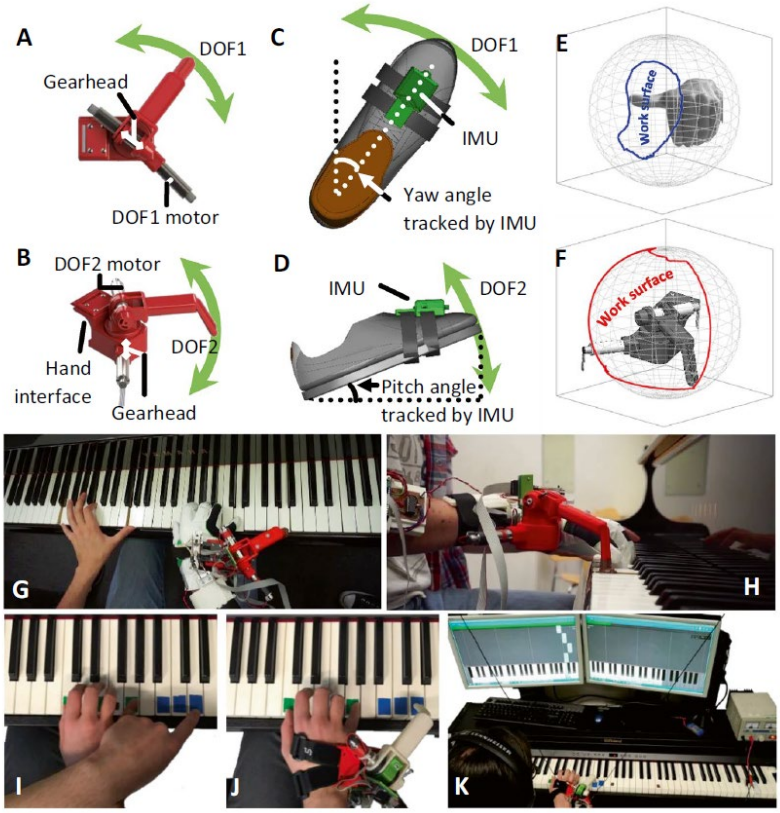


Figure 21 - Piano playing task setup. (A) Top view rendering of the SR3T, showing the horizontal motion DOF and relevant motor. (B) Side view rendering of the SR3T showing the vertical motion DOF and the relevant motor. (C) Top view rendering of the SR3T control interface for the 1st degree of freedom (DOF); the participant controls the motion of the SR3T using their right foot, captured through an inertial measurement unit (IMU) worn on the foot. (D) Side view rendering of the SR3T control interface for the 2nd DOF. (E) Work surface of a human thumb end-point projected on a sphere for comparison with (F) the work surface of the SR3T endpoint projected on a sphere—augmenting work surface range for the human (see methods). (G, H) Top and side view of the unconstrained pilot experiment: an experienced piano player freely improvising on the piano while wearing and making use of the SR3T, effectively playing 11-fingered piano within one hour of use. (I) Systematic experiments: playing the piano sequence using five fingers of the right hand plus the left-hand index finger (LHIF) and (J) Playing the sequence using the SR3T. (K) A participant plays the sequence of notes as displayed on the monitors in front of them, using the SR3T. Taken from Shafti et al.[547]

[543] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p667.
[544] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p665.
[545] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p667.
[546] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p670.
[547] Shafti et al., "Playing the piano with a robotic third thumb: assessing constraints of human augmentation," p3 Figure 1.

This study was followed up in 2021 by Shafti et al., who also described the Supernumerary 3rd Thumbs (SR3T), as seen in Figure 20. This figure also shows how the thumb is 'controlled through substitution, initially with a combination of the natural thumb and the foot wearing different sensing modalities.'[548] The SR3T has two degrees of freedom, similar to the earlier models, and is controlled by the user's body, as illustrated in Figure 20.

Shafti et al. note an important neurological difference found between polydactyl subjects born with six fingers and the rest of us born with five. They point out that in these special cases, the person with polydactyly has a 'cortical representation of the supernumerary finger' present at birth. Those who don't have this, as is the case for the rest of us, propose that success in augmentation is evidenced by 'understanding the role of human motor control in the success and adoption of these robotic human augmentation systems.'[549] Thus, they propose a motor coordination test called the Human Augmentation Motor Coordination Assessment (HAMCA).[550] By testing two sets of piano players, 'naïve piano players' and 'piano playing experts,' they noted the following: '[w]e saw no group difference in the performance with the SR3T, suggesting that integrating robotic augmentation is primarily driven by a priori motor coordination skills and not affected significantly by expert motor domain knowledge.'[551] Therefore, Sahfti et al. suggest that the augmentation capability of this study depends on individual motor coordination capability. However, as we shall see later, significant uncertainties about the neural allocation problem presented here raise questions.

This interest in augmentation and embodiment was preceded in 2015 by an important study conducted by a well-known research group that explored the concept of embodiment.[552] Many other researchers have subsequently cited their paper when the notion of embodiment is deployed as a research aim in supernumerary robotic finger augmentations. Sobajima et al. base their concepts of the Extra Robotic Thumb (ERT) design primarily on the premise that it must function as a fully tactile thumb with tactile feedback. They say, '[i]n order to embody, the embodiment method of imitating somatosensory is often used' to perceive the position of the SRF; a vibrotactile feedback

[548] Shafti et al., "Playing the piano with a robotic third thumb: assessing constraints of human augmentation," p6.
[549] Shafti et al., "Playing the piano with a robotic third thumb: assessing constraints of human augmentation," p2.
[550] Shafti et al., "Playing the piano with a robotic third thumb: assessing constraints of human augmentation," p2.
[551] Shafti et al., "Playing the piano with a robotic third thumb: assessing constraints of human augmentation," p6.
[552] Masafumi Sobajima et al., "Improvement of operability of extra robotic thumb using tactile feedback by electrical stimulation" (2015).

mechanism is deployed. [553] The thumb has three joints, '[i]t is attached to the on [the] left hand and controlled by the right-hand thumb.'[554] The thumb replicates the same motions as the other thumb, the right thumb.

Figure 22 - Image of ERT (Extra Robotic Thumb) showing (A) the ERT and its coupling with (B) The Thumb Motion Capture Device. Taken from Sobajima et al.[555]

This is illustrated in Figure 21. Each angle of movement radiates a vibration, but this is limited to four modes. This sends an electrical stimulation (ES) to the right thumb. It also sends ES to signify 'tactile force measured by sensors'[556] in and at the ERT tip. By testing participants in a study, by picking up and arranging bolts, as a fine motor skill task, Sobajima et al. were able to prove that their experiment for embodiment and accuracy of movement was the result of 'afferent input that is the tactile feedback. Therefore, the ERT was more strongly embodied'.[557] They continue to propose that '[i]n the future, we will use the feedback for angles of the ERT and make a challenge to perceive the

[553] Sobajima et al., "Improvement of operability of extra robotic thumb using tactile feedback by electrical stimulation," p1.
[554] Sobajima et al., "Improvement of operability of extra robotic thumb using tactile feedback by electrical stimulation," p1.
[555] Sobajima et al., "Improvement of operability of extra robotic thumb using tactile feedback by electrical stimulation," p1 Figure 1.
[556] Sobajima et al., "Improvement of operability of extra robotic thumb using tactile feedback by electrical stimulation," pg1.
[557] Sobajima et al., "Improvement of operability of extra robotic thumb using tactile feedback by electrical stimulation," p2.

position of the ERT without visual feedback.'[558] This study makes a significant contribution to understanding what is required to embody a third-thumb and how to transform a mere robotic artifact into a fully interactive robotic appendage. Prattichizzo et al., who reviewed Sobajima et al.'s ERT, say it is among the 'most relevant supernumerary fingers prototypes developed in recent years. It has been used in several studies as a platform for investigating different control and feedback modalities.'[559]

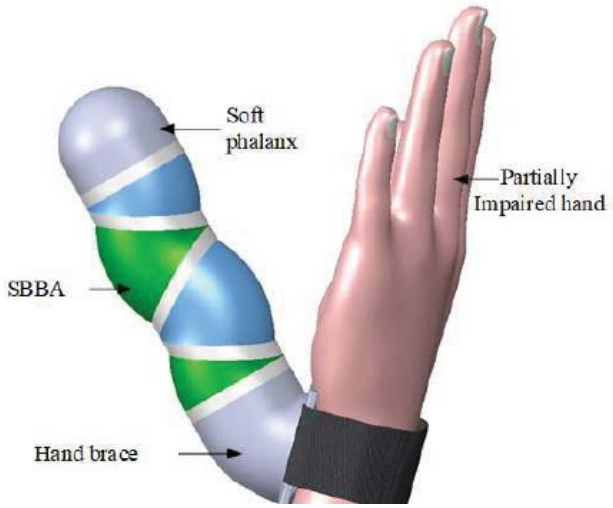


Figure 23 - Soft Robotic device using Soft Biodirectional Bending Actuators (SBBA) for assistance. Taken from Singh et al.[560]

Earlier in this chapter's introduction, while exploring the trends in SRFs and their innovations, soft SRFs were applauded. The various reviewers suggested it as the future of SRF development. In 2019, Singh et al. designed an 'appendage', which they have not called a finger but is worn on the wrist, called the Soft Bidirectional Bending Actuator for Human-Robot Interaction.[561] Its innovations are in its namesake, as seen in Figure 22. Its design uses a 'fully pneumatic fibre-reinforced soft bidirectional bending actuator (SBBA) made up of soft pneumatic rotary actuator (SPRA).'[562] They highlight the need for such wearable devices to be 'flexible, lightweight and able to accomplish effortless grasping of a variety of objects.

[558] Sobajima et al., "Improvement of operability of extra robotic thumb using tactile feedback by electrical stimulation," p2.
[559] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p7.
[560] K. S. Singh and A. Thondiyath, "Design and Analysis of a Soft Bidirectional Bending Actuator for Human-Robot Interaction Applications" (paper presented at the 2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN), 14-18 Oct. 2019 2019), p2 Figure 2.
[561] Singh and Thondiyath, "Design and Analysis of a Soft Bidirectional Bending Actuator for Human-Robot Interaction Applications."
[562] Singh and Thondiyath, "Design and Analysis of a Soft Bidirectional Bending Actuator for Human-Robot Interaction Applications," p2.

Additionally, the device should be customizable as per the user's needs.'[563] Prattichizzo et al. refer to this as an 'intrinsically compliant supernumerary finger.'[564] The advantage of this novel SRF is that it incorporates safety considerations into the design, providing additional degrees of freedom (DoF) for grasping various types of objects.

As mentioned in the introduction to this chapter, we will not consider exoskeletons as part of the scope when considering a third-thumb or SRF. The next SRF, however, is worthy of mention (even though it incorporates an exoskeleton) because of its soft, telescopic extra thumb embedded in an exoskeleton glove. In 2020, Gerez et al. introduced their 'hybrid (tendon-driven and pneumatic), lightweight, affordable, easy-to-operate exoskeleton glove equipped with variable stiffness, laminar jamming structures, abduction/adduction capabilities, and pneumatic telescopic extra thumb that increases grasp stability.'[565] Figure 23 clearly shows the components and innovations in the SRF. These systems demonstrate how the glove and its telescopic extra third-thumb assist in grasping. It seems very innovative and intuitive to use.

Figure 24 - The soft glove system of the device consists of a glove, a tendon-driven system, and a pneumatic system that is composed of four soft actuators and five laminar jamming structures. Five plastic tendon termination structures are stitched onto the fingertip regions of the glove. The tendon-driven system has a tendon connected to each of the tendon termination structures and an extra tendon that is connected to the thumb's interphalangeal joint region, facilitating the execution of the opposition motion. The soft structures are used for three different purposes: to perform abduction and adduction of the fingers, to enhance grasp stability by incorporating an extra thumb structure, and to modify the bending profile of the fingers. Three of the pneumatic chambers are connected to the region between the fingers, allowing for the execution of the abduction and adduction motion of the fingers. Another soft actuator was designed to function as a

[563] Singh and Thondiyath, "Design and Analysis of a Soft Bidirectional Bending Actuator for Human-Robot Interaction Applications," p1.
[564] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p8.
[565] Lucas Gerez et al., "A Hybrid, Wearable Exoskeleton Glove Equipped With Variable Stiffness Joints, Abduction Capabilities, and a Telescopic Thumb," *IEEE access* 8 (2020): p173345, https://doi.org/10.1109/ACCESS.2020.3025273.

telescopic extra thumb, participating in grasping tasks by increasing the area of contact between the hand and the object, thereby enhancing both grasp efficiency and stability. At the back of the glove, five laminar jamming structures were added to adjust the stiffness of the joints and to enable passive extension of each finger, thereby maintaining the hand in its natural, zero-effort position. A flex sensor is located on the index finger and can be used to control the motion of the exoskeleton glove, as described in Gerez et al.[566]

The next project diverges from the mechatronic solution-finding propositions considered so far. It shifts the direction of SRFs towards what has been emerging as the next important factor in researchers' thinking, namely, tackling the core issue of cognitive acceptance. When designer and artist Danielle Clode collaborated with Paulina Keiliba's team in Professor Tamar Makin's laboratory, a very fruitful project was initiated at University College London under the auspices of the Plasticity Lab. The Lab 'investigates the extent to which brain areas supporting perception and action are shaped by experience, with particular focus on what happens to the cortical territories of the hand'.[567] The design of the Clodes' SRF, or Third Thumb, is noteworthy not only because of its simplicity in terms of electronic complexity but also due to its aesthetics, ease of use, embodied design, and creativity.

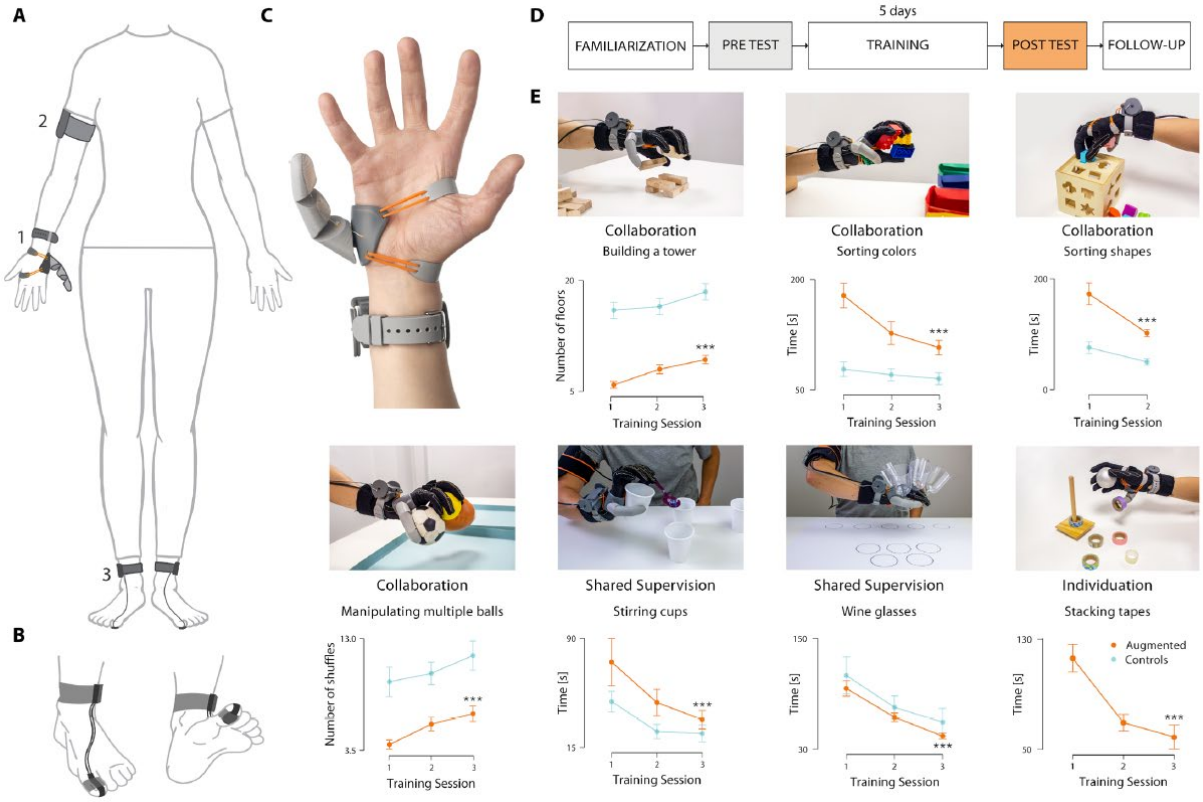


Figure 25 - The Third Thumb. Experimental design of the study. (A to C) The Third Thumb is a 3D-printed robotic thumb. Mounted on the side of the palm (1), the Thumb is actuated by two motors (fixed to a wristband), allowing for independent control over flexion and adduction. The Thumb is powered by (2) an external battery, strapped around the arm and

[566] Gerez et al., "A Hybrid, Wearable Exoskeleton Glove Equipped With Variable Stiffness Joints, Abduction Capabilities, and a Telescopic Thumb," p173348 Figure 3.
[567] "Plasticity," Institute of Cognitive Neuroscience, University College London, 2023, accessed Sep 2023, 2023, https://www.ucl.ac.uk/icn/plasticity.

*wirelessly controlled by (3) two force sensors fixed to the underside of the participant's big toes. (D) Experimental design for the augmentation group. (E) Examples of the in-lab training tasks used for hand-Thumb collaboration, shared supervision, and Thumb individuation. Participants in the augmentation group demonstrated significant performance improvements on all tasks throughout the training sessions. The dots depict group means, and error bars indicate SEM. Asterisks denote a significant effect of time at ***P < 0.001, taken from Kieliba et al.*[568]

A paper produced by Keiliba et al. in Figure 24 describes it as such:

> The Thumb [called the Third Thumb] is worn over the ulnar side of the right palm, opposite to the user's natural thumb. It is actuated by two motors, allowing proportional control of two independent degrees of freedom, flexion/extension and adduction/abduction. The motors are mounted on a wrist strap and powered by an external battery pack worn on the upper arm. The movement of the Thumb is controlled with pressure sensors fixed to the underside of the big toes of the user's feet. The pressure sensors are powered by external batteries secured around the ankle. A wireless communication protocol is used to send the signal from the pressure sensors to the motors that actuate the Thumb. Pressure exerted with the right toe pulls the Thumb across the hand (flexion), whereas the pressure exerted with the left toe pulls the Thumb up towards the fingers (adduction). The extent of the Thumb movement is fully proportional to the pressure applied.[569]

This Third Thumb, has garnered much attention on YouTube[570] and in the news media. I would suggest that it is due to the natural scale of its aesthetics, its elegance, and usability that make it so interesting. This type of aesthetic resonates with our habitual thinking of a third-thumb. Kieliba et al*.,* however, are keenly interested in the critical factors underlying SRF acceptance: the 'brain's ability to learn, adapt and interface with augmentation devices […], increased sense of embodiment'[571], the correlations with hand representation and effects on motor control. This is a very complex and ambitious study, and I will quote Kieliba et al. at length because their description covers so much of the territory with which this dissertation is concerned:

> Hand augmentation could benefit diverse groups of people, from factory workers to surgeons […]. This vision depends on not only on the exciting technological innovations but also critically relies on our brain's ability to learn, adapt, and interface with these devices. Therefore, as technology becomes more integrated with the human body, we see new challenges and opportunities emerging from neural and cognitive perspectives. Critical questions arise as to how such human-machine integration can be best achieved, given the expected neurocognitive bottlenecks of brain plasticity. Here, we demonstrated that successful integration of motor augmentation can be readily achieved, with potential for flexible use, reduced cognitive reliance, and increased sense of embodiment. However, such successful human-robot integration may have direct consequences on key aspects of body

[568] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p2 Figure 1.
[569] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p2.
[570] "Controllable Third Thumb lets wearers extend their natural abilities," YouTube, July 2017, 2023, https://www.youtube.com/watch?v=TY6Dm4Klumc.
[571] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p1.

representation and motor control, be it adaptive or maladaptive, which need to be understood and explored further before this technology can be widely implemented.[572]

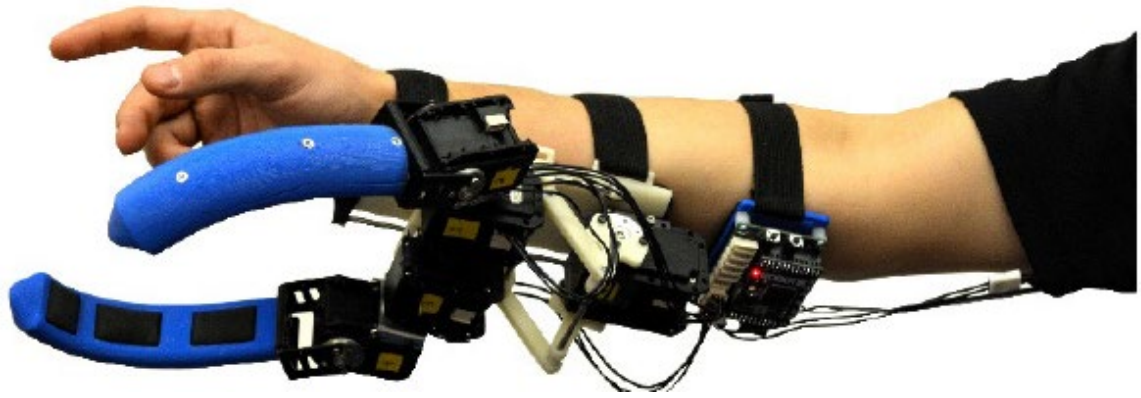


Figure 26 - Wrist-mounted SR Finger prototype developed to assist with therapist-guided ADL rehabilitation training. Taken from Ort et al.[573]

The next prototype for consideration is the Supernumerary Robotic Fingers (SR Fingers), as seen in Figure 25, which was developed in collaboration between Teddy Ort, Harry Asada and Wu Fay, notable researchers in the field who have produced earlier works. This bears mention even though it was developed to 'facilitate therapist-guided ADL [Activity of Daily Life] training'[574] for hemiparetic patients with some arm and hand function, and not specifically for augmentation to healthy hands. Ort et al. developed the SR Fingers prototype, a wearable device with two fingers. This SRF is mounted on the wrist while each finger is fully actuated and has 2 DoF for flexion and extension. An additional DoF runs along the arm to allow patients to customise its position and, hence, the workspace of the fingers in relation to other natural fingers. Ort et al. tell us that three textured rubber pads were fixed to each finger to increase the friction between the finger and the object. The pads also had a smaller air bubble behind them to add compliance. The control of the SR Fingers is performed by a sensor glove worn on the healthy hand, which responds to certain motions to help intuitively control the SR Fingers. This programmable and adjustable prototype enables fully able users to wear the SR Fingers. The SR Fingers were not designed for highly dexterous movements such as tying shoelaces, buttoning shirts, or more complex hand motions.[575]

[572] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p7.
[573] Teddy Ort et al., *Supernumerary Robotic Fingers as a Therapeutic Device for Hemiparetic Patients* (2015), p2 Figure 1.
[574] Ort et al., *Supernumerary Robotic Fingers as a Therapeutic Device for Hemiparetic Patients*, p1.
[575] Ort et al., *Supernumerary Robotic Fingers as a Therapeutic Device for Hemiparetic Patients*, p5.

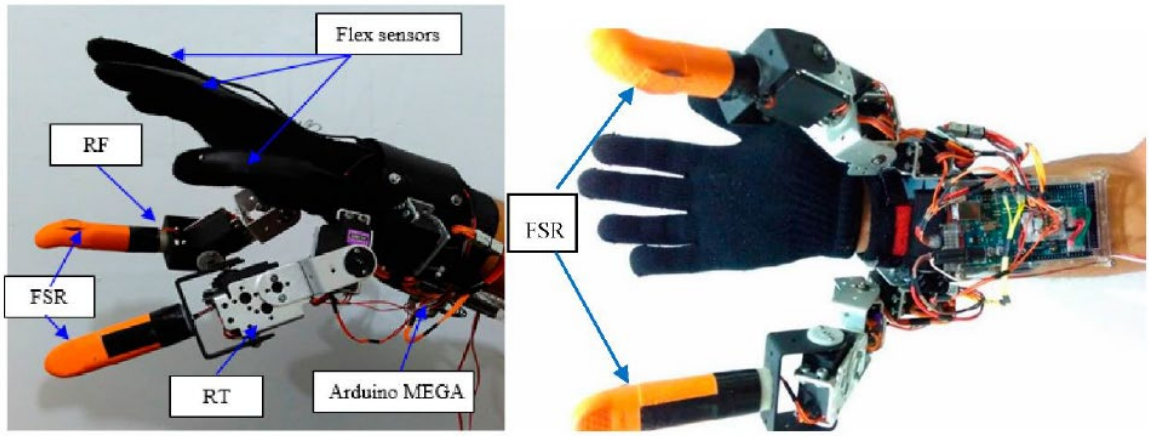


Figure 27 - Developed prototype Extra Robotic Fingers for assisting bimanual tasks. Taken from Setiawan et al.[576]

Similar to an earlier design, Setiawan et al. produced an SRF artifact with two Extra Robotic Fingers, one 'robotic thumb (RT)', attached next to the user's thumb, and a 'robotic finger (RF) […] is located next to the user's little finger',[577] as seen in Figure 26. They published a paper in 2020 on the investigation of how neural networks can improve the efficiency of grasp motion, titled 'Grasp Posture Control of Wearable Extra Robotic Fingers with Flex Sensorys Based on Neural Networks'.[578] The neural network algorithms are fed using multiple embedded flex sensors in a custom-built glove called the iGlove mechanism, which collects data from the user's hand to determine the most productive predictive motion. As explained by Setiawan et al., '[t]hese signals will be fed to the trained neural network regression to estimate the commanded angles for the servo motors in the extra robotic fingers.'[579] The fingertips of the Extra Robotic Fingers have been designed like the fingertips of a real hand, as seen in Figure 26. And these fingertips are 'equipped with force-sensitive resistors (FSR), and are attached to the fingertips […] to incorporate a haptic feedback system.'[580] The results of such an innovation showed that the Extra Robotic Fingers could operate more intuitively and efficiently. The Extra Robotic Fingers give significantly more dexterity when working with both hands of healthy users and those with hemiplegia or hemiparesis.[581] A noteworthy point is the somatosensory feedback system. Research such as that carried out by Zhu et al. has shown that

[576] Setiawan et al., "Grasp posture control of wearable extra robotic fingers with flex sensors based on neural network," p4 Figure 2.
[577] Setiawan et al., "Grasp posture control of wearable extra robotic fingers with flex sensors based on neural network," p1.
[578] Setiawan et al., "Grasp posture control of wearable extra robotic fingers with flex sensors based on neural network."
[579] Setiawan et al., "Grasp posture control of wearable extra robotic fingers with flex sensors based on neural network," p20.
[580] Setiawan et al., "Grasp posture control of wearable extra robotic fingers with flex sensors based on neural network," p2-3.
[581] Setiawan et al., "Grasp posture control of wearable extra robotic fingers with flex sensors based on neural network," p18.

'somatosensory feedback from finger tips [sic] has a large contribution for the update of sense of self-location' and is a dominant factor in embodiment.'[582]

Forearm-mounted

This section reviews the SRFs that are worn around the forearm.

In the previous section, we mentioned that Hussain et al. presented two sixth-finger prototypes in 2016. One was the Soft Sixth Finger, which was worn around the wrist, followed later that year by the Double Soft Sixth Finger[583], which is more readily forearm-mounted for stability and payload purposes. Both prototypes are seen here in Figure 17, and the Double Sixth Finger is seen in Figure 27.

Figure 28 - (A) Final prototype of double soft sixth finger. (B) The double soft sixth finger in the bracelet position.Taken from Hussain et al.

There is a distinction to be made between the two types of SRF, as Hussain et al. explain, '[a]lthough the soft sixth finger can be used to grasp and stabilise a large set of objects, having a single finger in opposition to the patient's arm can result in a limitation in tasks requiring a high payload.'[584] The innovation in this underactuated Double Sixth Finger utilises a single actuator to control the device's

[582] Zhu et al., "Development of sense of self-location based on somatosensory feedback from finger tips for extra robotic thumb control."
[583] Hussain et al., "Toward wearable supernumerary robotic fingers to compensate missing grasping abilities in hemiparetic upper limb."
[584] Hussain et al., "Toward wearable supernumerary robotic fingers to compensate missing grasping abilities in hemiparetic upper limb," p11.

motion, in conjunction with a tendon pulley system that winds the fingers into flexion to grasp objects and releases them to allow extension, opening the fingers. The fingers are unobtrusive and can be shaped into bracelets when not in use. The actuator controller and battery are positioned on the user's belt. At the same time, the device can be set anywhere along the arm depending on the 'patient conditions and the residual mobility of the arm/hand.'[585] The fingers can be positioned at the most distal part of the arm, near the wrist, or at the most proximal part, allowing for customisable grasping because the fingers can then be translated along the forearm for suitable orientation. The velcro and elastic arms ensure comfort. As with the Soft Sixth Finger, an eCap device interface uses EMG signals from the patient's frontalis muscles when moving the eyebrows to help control the finger motion.[586]

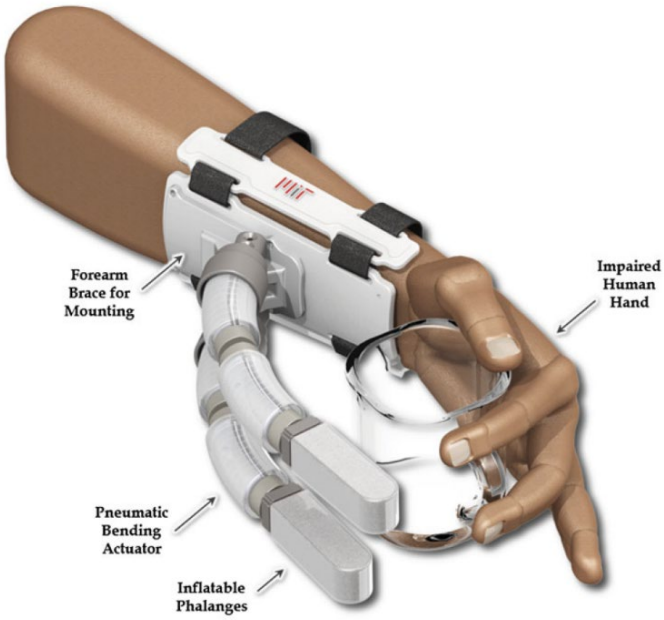


Figure 29 -Pneumatic supernumerary robotic (SR) fingers being used to provide grasp assistance to individuals suffering from stroke-induced hand impairment. Taken from Hammond et al.[587]

Earlier in this chapter, we noted the resounding opinions of various researchers on future innovations in soft robotics, utilising soft actuators and materials. One such reviewer was Tong et al., among the four primary reviewers noted in the opening to this chapter, who extolled the virtues of these innovations due to their safety, compliance, and weight-to-load ratios. The reviewers cited one paper in 2018 by Hammond et al., who are seen as among the first to fully produce a 'pneumatic

[585] Hussain et al., "Toward wearable supernumerary robotic fingers to compensate missing grasping abilities in hemiparetic upper limb," p12.
[586] Hussain et al., "Toward wearable supernumerary robotic fingers to compensate missing grasping abilities in hemiparetic upper limb," p13-14.
[587] Frank L. Hammond Iii, Faye Wu, and H. Harry Asada, "Variable Stiffness Pneumatic Structures for Wearable Supernumerary Robotic Devices" (Cham, 2018), pg203 Figure 1.

supernumerary robotic (SR) finger device […] as a means of improving the portability, controllability, and reconfigurability of grasp assist devices'[588], seen in Figure 28. It has two fingers or phalanges and is designed for ADLs, such as picking up cups, bowls, and opening door knobs, but 'not the dexterous manipulation capabilities associated with fine motor skills in healthy subjects.'[589] The features of this device include a modular, inflatable structure, which has fewer power requirements, and 'tunable bending actuators, which make grasp motion programming and device control less challenging.'[590] This paper contributes to the analysis and component testing of complex technical, functional, mechanical, deformational, and performance properties. Through these investigations, Hammond et al. can identify better programming synergies for configuring such properties. In their own words, Hammond et al. summarise their contributions in this way:

> This paper presents the design, analysis, and experimental validation of novel variable stiffness pneumatic bending actuators and inflatable semi-rigid phalanges for programming motion synergies in wearable robotic devices. Soft robot fabrication methods are presented and functional performance specifications, including motion range and stiffness, are modelled and experimentally validated. Grasp assist trials using the pneumatic SR grasp assist device demonstrate the ability to strategically modulate actuator motion to produce grasps suited to specific objects.[591]

[588] Hammond Iii, Wu, and Asada, "Variable Stiffness Pneumatic Structures for Wearable Supernumerary Robotic Devices," p202.
[589] Hammond Iii, Wu, and Asada, "Variable Stiffness Pneumatic Structures for Wearable Supernumerary Robotic Devices," p204.
[590] Hammond Iii, Wu, and Asada, "Variable Stiffness Pneumatic Structures for Wearable Supernumerary Robotic Devices," p202.
[591] Hammond Iii, Wu, and Asada, "Variable Stiffness Pneumatic Structures for Wearable Supernumerary Robotic Devices," p216.

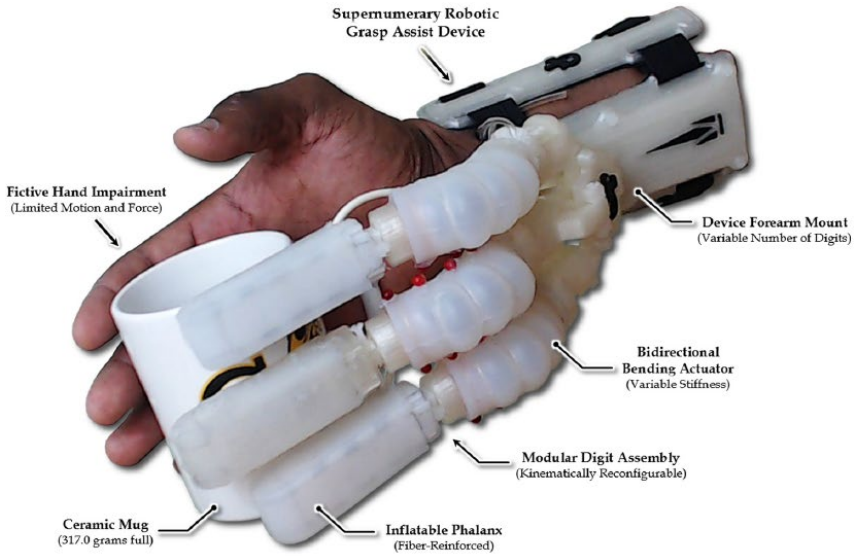


Figure 30 - Prototype of a pneumatic supernumerary robotic grasp-assist device. The major device components and their relevant functional features are labelled. This particular grasp involves minimal human user effort, where the digits are not required to conform to secure the mug; it is primarily provided by the device and the stiffening of the metacarpophalangeal joints, as described by Tizian et al.[592]

Other researchers, such as Tiziani et al., have built upon the work of Hammond et al. Although their paper was officially published a year earlier, in 2017, Tizian et al. acknowledged and built upon their predecessors' work.[593] Maybe this anomaly is explained by the fact that Frank Hammond is also a collaborator and co-author of this latest paper. It will suffice to summarise the technical innovations of Tiziani et al. directly from their abstract and then focus on the prototype, referred to here as the 'supernumerary grasp-assist device', seen in Figure 29, in general terms rather than its technical details. The paper presents 'the design, fabrication and experimental characterisation of modular, variable stiffness inflatable components for pneumatically actuated supernumerary robotic (SR) grasp-devices'[594]. This device features a two- or three-digit supernumerary robotic grasp-assist device architecture, positioned opposite the palm on the patient's forearm or wrist, utilising the paretic hand with limited motion as a stabiliser.

In contrast, the fingers are actuated to bend and flex at will. Tizian et al. argue that '[t]his device, in essence, becomes a fluidic version of the cable-pulley mechanism used for passive, underactuated

[592] Lucas Tiziani et al., "Empirical characterization of modular variable stiffness inflatable structures for supernumerary grasp-assist devices," *The International journal of robotics research* 36, no. 13-14 (2017): p 1392 Figure 1, https://doi.org/10.1177/0278364917714062.
[593] Tiziani et al., "Empirical characterization of modular variable stiffness inflatable structures for supernumerary grasp-assist devices," p1393.
[594] Tiziani et al., "Empirical characterization of modular variable stiffness inflatable structures for supernumerary grasp-assist devices," o1391.

grasping'[595] found in previous SRF examples discussed above. The 'proposed SR grasp-assist devices are comprised of soft rigidizable [sic] finger phalanges and variable stiffness pneumatic bending actuators that are manufactured using soft lithography fabrication methods.'[596] This allows for the construction of such devices from soft, modular, rigidizable (able to be made rigid) structures that can reduce power input using bending actuators, making grasp programming easier, more economical to perform and programmable with hand and joint data synergies, more adaptive and reconfigurable and can customise the SR grasp-assist device to treat a variety of patient hand disabilities.[597]

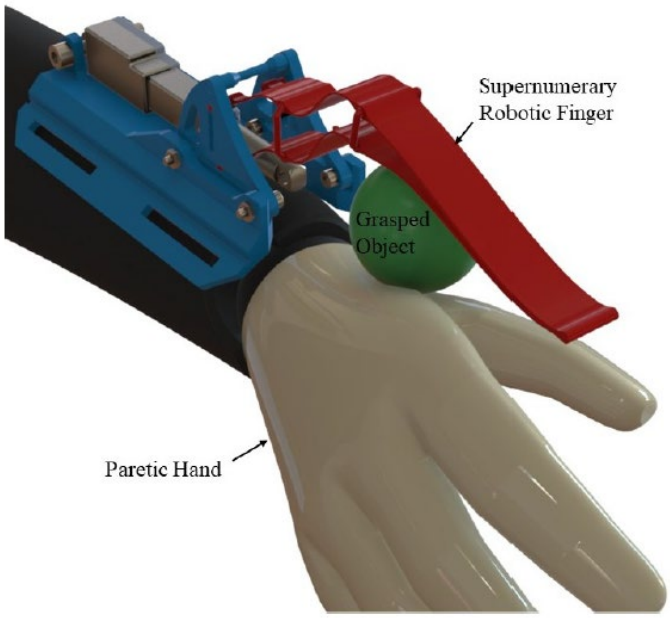


Figure 31 - The concept of a supernumerary robotic finger. The robotic finger and human arm act as two parts of the gripper to grasp an object. Taken from Hussain et al.[598]

Other innovations are continually being sought to address the disadvantages of rigid, actuated SRFs. Another innovation Hussain et al. developed in 2019 to respond to advancements in robotic finger mechanisms was the prototype of a Supernumerary Robotic Finger, inspired by the Fin Ray Effect—a 'underactuated device inspired by the physiology of fish fins.'[599] As seen in Figure 30, the structure of the supernumerary robotic finger is similar to that of other types of SRF designed for sensorimotor

[595] Tiziani et al., "Empirical characterization of modular variable stiffness inflatable structures for supernumerary grasp-assist devices," p1394.
[596] Tiziani et al., "Empirical characterization of modular variable stiffness inflatable structures for supernumerary grasp-assist devices," p1391.
[597] Tiziani et al., "Empirical characterization of modular variable stiffness inflatable structures for supernumerary grasp-assist devices," p1393.
[598] Irfan Hussain et al., "Design and Prototype of Supernumerary Robotic Finger (SRF) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment" (2019), p398 Fig1.
[599] Hussain et al., "Design and Prototype of Supernumerary Robotic Finger (SRF) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment."

hand impairments, where the palm or the paretic hand acts as one side of a two-sided gripper. The innovations are derived from the simplified structure and limited actuators, allowing the SRF to have 'unidirectional or omnidirectional compliance.'[600] It also acts in a 'closed chain manipulator structure'[601], meaning that the movement of one joint causes the other joints in the chain to move in the same predicted manner. The character of the embodied material used here also aids in the types of shapes and more unstructured environments in which this SRF can be utilised. This is due to its ability to adapt to various uncertain shapes. The control mechanism is very simple and uses 'push buttons to control the motion of the device and LEDs (Light Emitting Diodes) to show the status of the finger.'[602] As Yang et al. summarise, this quality of omnidirectional compliance has an ergonomic advantage by clarifying that the '[e]rgonomics and functional requirements mainly refer to comfort, usability, grasp ability, and compliant structure'[603]. This SRF meets all of these requirements.

What is concerning regarding the aim of most of these researchers is that their stated intentions vacillate between augmentation and compensation within a single paragraph. It leaves the reader uncertain about the research's aims. And I don't think it is clear on any ethical, aesthetic, social or political grounds why they are doing this research other than to innovate within the medical context for those with disabilities. The two subjects of augmentation or compensation should be clearly and distinctly separated because the neurocognitive and neural allocation issues are still being researched, as well as their application and use in wider society, as previously discussed.

We see an example of this in the opening sentence of the abstract in the paper 'Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation' by Malvezzi et al., published in late 2019. They say, '[a]ugmenting the human hand with robotic extra fingers is a cutting-edge research topic and has many potential applications, in particular as a compensatory and rehabilitation tool for patients with upper limb impairments.'[604] Later in their discussion, they say, '[a] rather new research branch in wearable robotics deals with human body augmentation.'[605] Augmentation poses distinctly different cognitive challenges than the compensatory aims of prosthetics, as has already been indicated. Later in their paper, Malvezzi et al. say, '[s]upernumerary limbs will provide novel

[600] Hussain et al., "Design and Prototype of Supernumerary Robotic Finger (SRF) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment," p398.
[601] Hussain et al., "Design and Prototype of Supernumerary Robotic Finger (SRF) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment," p398.
[602] Hussain et al., "Design and Prototype of Supernumerary Robotic Finger (SRF) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment," p401.
[603] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p625.
[604] Monica Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," *Robotics (Basel)* 8, no. 4 (2019): p1, https://doi.org/10.3390/robotics8040102.
[605] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p17.

opportunities to recover missing abilities, resulting in improvements of patients quality of life'[606]. There is a lack of clarity regarding the aims and motives for research, and no clear vision beyond these simple aims, except in this instance.

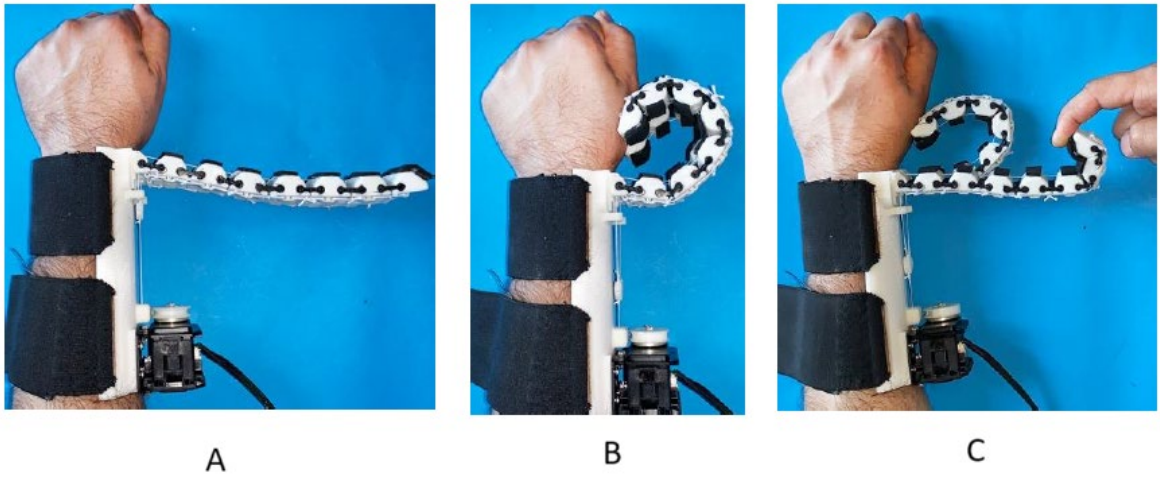


Figure 32 -The prototype of the Double Robotic Extra Fingers, consisting in two wearable extra fingers, worn by a user. (A) Reference open configuration. (B) Closed configuration. (C) Example of how the differential mechanism decouples the motion of the fingers, so that the device can adapt to different surfaces and object shapes. Taken from Malvezzi et al.[607]

Malvezzi et al.'s Double Robotic Extra Fingers project is significant because it allows a differential mechanism to actuate the double fingers using a single actuator. This is easier to understand visually, as shown in Figure 31. When one motor is used, the flexion of both fingers occurs until an object is touched or grasped. If one finger stops, so does the other under normal circumstances, because they are using the same actuator. Decoupling or creating a differential mechanism allows the second finger to continue flexing until it, too, touches the objects, giving the fingers differential curvatures or grasping capability. Malvezzi et al. explain this in the following way: '[f]or a double robotic extra finger, that is a device with two outputs and one input, a simple differential mechanism can be used to decouple finger motions when one of them is constrained.'[608] This allows wearable robotic fingers to adapt to irregular objects with different surfaces and multiple objects using 'a single tendon'[609] given that a single tendon actuates each finger.[610] The co-authors of this paper are Domenico Prattichizzo and Gionata Salvietti, who have worked on other papers with Ifran Hussain. They deploy the same interfaces used in their other research into this project. The Double Robotic Extra Finger can be controlled both with the eCap, 'an Electromyography (EMG) interface embedded

[606] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p18.
[607] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p102 Figure 1.
[608] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p2.
[609] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p3.
[610] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p4.

in a cap', or the hRing; 'a ring that can be worn by the user on the healthy hand, provided by buttons for opening/closing the wearable extra fingers and with a vibrating motor providing a haptic cutaneous feedback stimulus to the user's healthy hand.'[611] The advantage of this Double Robotic Extra Finger is that it enables a more secure grasping capability, providing a more stable grasp that allows users to carry heavier loads.

Such small technical achievements are piecemeal advances that cumulate in revolutions in SRF development. A technical example cited here demonstrates that improvements happen in increments. An innovation in decoupling double finger movement using one actuator, like the above example, happens this time in the decoupling capacity of the SRF interfaces to 'detect and reject disturbances [mostly unintentional] caused by the wearer's motion.'[612] As Faye Wu and Harry Asada explain in their 2018 paper, opening a bottle cap is not as simple as it appears. The robot working on the arm motions will also tend to twist with the bottle and rotate in the same direction. Their decoupling experiment intends to use the 'data-driven latent space impedance control method'[613] to compensate and secure the bottle while allowing the natural hand to carry out its manoeuvre to open it, therefore ignoring what they term a human disturbance. This allows the SRF to work with the natural hand to 'enable single-handed object manipulation'[614]. These particular grasps are important in ADL, where cutting with scissors, tearing open a sealed bag, and pulling up a zipper are typical actions that require this uncoupling to allow for hand dexterity.

[611] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p16.
[612] Faye Y. Wu and H. Harry Asada, "Decoupled Motion Control of Wearable Robot for Rejecting Human Induced Disturbances" (2018), p4103.
[613] Wu and Asada, "Decoupled Motion Control of Wearable Robot for Rejecting Human Induced Disturbances."
[614] Wu and Asada, "Decoupled Motion Control of Wearable Robot for Rejecting Human Induced Disturbances," p4103.

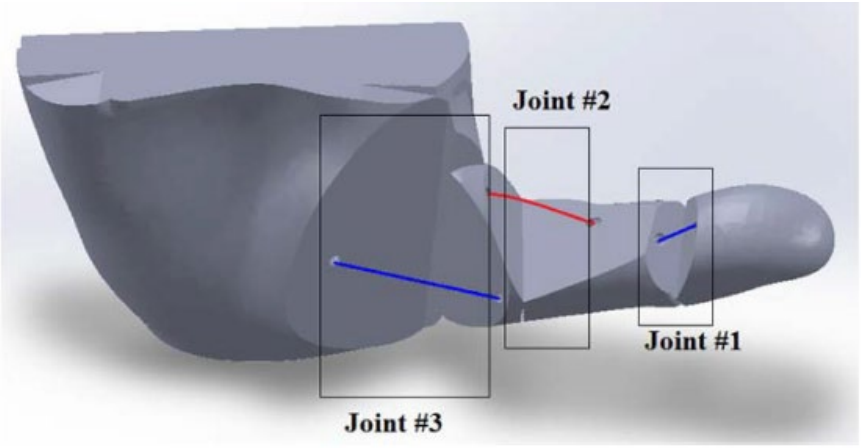


Figure 33 -The CAD design of a multi-joint soft robotic thumb (shown together with a hand palm), the tendons' routes inside the structure not shown, taken from Hao et al.[615]

In advancing the boundaries of an underactuated system, another advancement that furthers usability in SRF technology is this next project, which innovates by using one electric motor to drive in two directions. Hoa et al. emphasise that 'each of [sic] rotations can provide actuation to an individual tendon system, which means the two tendon systems can be separately actuated by one electric motor.'[616] In their paper 'A Novel Monolithic Soft Robotic Thumb for an Anthropomorphic Prosthetic Hand' published in 2019, Hao et al. developed a prosthetic hand similar in size and scale to a human hand. Their work centred around providing full functionality to the thumb, meaning that it was capable of abduction/adduction and flexion/extension using a 'single actuator providing both modes of operation.'[617] As shown in Figure 32, the thumb is operated by two tendon systems, each controlled by a single actuator. That single actuator provides an innovative and compact solution, as explained in Figure 33.

[615] Hao et al., "A Novel Monolithic Soft Robotic Thumb for an Anthropomorphic Prosthetic Hand," p603 Figure 1.
[616] Hao et al., "A Novel Monolithic Soft Robotic Thumb for an Anthropomorphic Prosthetic Hand," p605.
[617] Hao et al., "A Novel Monolithic Soft Robotic Thumb for an Anthropomorphic Prosthetic Hand," p603.

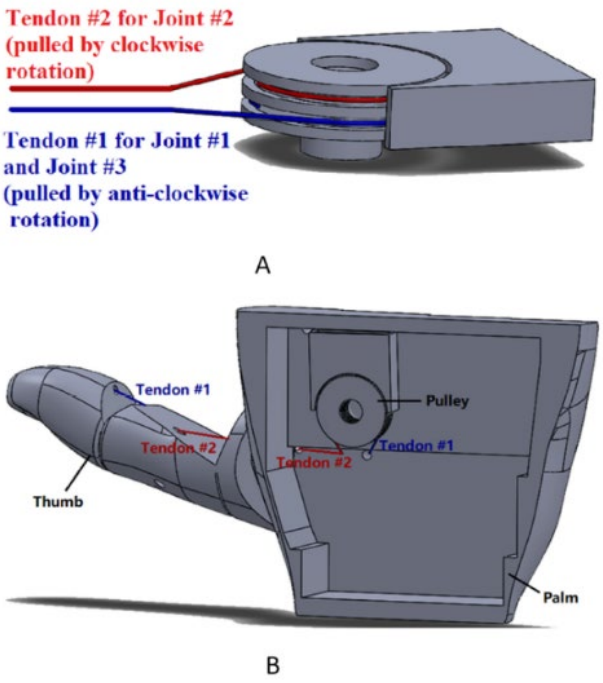


Figure 34 - (A) Concept of modality selection to separately actuate two tendon systems of the robotic thumb (B) the connection of the pulley/motor and the thumb (the tendons' routes inside the structure not shown). Taken from Hao et al.[618]

Given that the researchers Hao et al. are looking at a full hand-designed as a prosthetic, the concept can also be potentially applied to other SRF technologies. Hao et al.'s Soft Robotic Thumb is at the centre of the hands' design capability to harness the natural human capacities of the thumb. This allows the thumb to function while the hand performs the various grasps that make it so unique. Hao et al. suggest that '[a]mong these identified grasps and gestures, the top three are power grasp (used for 40% ADLs), precision grasp (pinch or tripod grip, used for 30% ADLs), and lateral (or key) grasp (used for 10%) ADLs).'[619] These grasps and their importance were discussed earlier when referring to the significance of Napier's descriptions of hand grips in human evolutionary terms. The control mechanism for this prosthetic hand utilises myoelectric signals from the residual forearm, collected using EMG electrodes.

[618] Hao et al., "A Novel Monolithic Soft Robotic Thumb for an Anthropomorphic Prosthetic Hand," p605 Figure 3.
[619] Hao et al., "A Novel Monolithic Soft Robotic Thumb for an Anthropomorphic Prosthetic Hand," p603.

Figure 35 - Tests on the SRS flippers. (a) Test setup for measuring the maximum payload capacity of the bare-bone prototype at different orientation, (b) the payload plot indicating the SSR flippers were able to carry load as 50 times heavy as its self-weight; (c) when worn on human forearm, the flippers can open, close and compactly wrap around the arm, (d) the flipper were able to perform a combination of abduction/adduction manoeuvres in a folded state, displaying the advantages of the dexterity, (e) the adaptiveness to daily objects were demonstrated, a new hugging function was introduced, taken from Liu et al.[620]

Returning to other projects that are nature-inspired SRFs like that of Hussain et al.s' 2019, a prototype of a Supernumerary Robotic Finger inspired by the Fin Ray Effect—there are researchers like Liu et al. with insights into another inspired idea provided also by nature. Liu et al. present their paper, 'Otariidae-Inspired Soft-Robotic Supernumerary (SRS) Flippers by Fabric Kirigami and

[620] Sicong Liu et al., "Otariidae-Inspired Soft-Robotic Supernumerary Flippers by Fabric Kirigami and Origami," *IEEE/ASME transactions on mechatronics* 26, no. 5 (2021): p2755 Figure 8, https://doi.org/10.1109/TMECH.2020.3045476.

Origami,' published in 2020. Referred to as the SRS Flippers, its design promises a softer, safer, lighter system worn on the forearm, 'inspired by the fore flippers of otariids (ear seals).'[621] The Otariidae foreflippers possess unique anatomical characteristics that enable them to be dexterous on both land and water. The Otariidae seal's flippers ergonomically fold to allow for gliding in the water when not in use. This unique invention is best understood visually, as shown in Figure 34. The SRS Flipper device is controlled by what is known as a 'cascade control structure', which simply uses pressure-control and pressure feedback information from the posture of the arm to estimate 'abduction/adduction, flexion and engagement signal'.[622] Besides those mentioned above, the advantage of this device is that it also allows for 'increased dexterity and load-to-weight ratio' as assessed by reviewers Prattichizzo et al.[623]

Out of scope for this review are SRF with several supernumerary fingers that represented full hands or exoskeletons that weren't SRF proper, as per the definition of this dissertation. However, despite this, we have covered a few of them to demonstrate particular technological innovations applicable to the SRF ontology. One of these SRFs is one with more than two fingers, which tends to converge into something like an extra hand, which is super interesting. The project I am about to discuss is an SRF, specifically designed for prosthetic hand compensation. In such examples, the extra thumb designs often become secondary to the aims of the entire prototype. In these cases, the third-thumb becomes a gripper rather than a true thumb.

An example would be Ciullo et al.'s paper, 'A Supernumerary Soft Robotic Hand-Arm System for Improving Worker Ergonomics', published in 2019. This research paper aims to reduce the vibrational transmission that overloads and fatigues users while using this SRF come-hand artifact.[624] These types of research projects are strongly premised on the development of specific devices for rehabilitation in stroke patients.

At the beginning of this chapter, we stated that we were more interested in augmentation as opposed to compensation; however, throughout, we have noted how researchers have found their work worthy of both fields by leveraging its applications in either healthy patients or those with lost finger or hand function. Whether they are hedging their bets or not is not the issue here. It is noteworthy to mention a few additional projects that are innovating in this field.

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[621] Liu et al., "Otariidae-Inspired Soft-Robotic Supernumerary Flippers by Fabric Kirigami and Origami," p2747.
[622] Liu et al., "Otariidae-Inspired Soft-Robotic Supernumerary Flippers by Fabric Kirigami and Origami," p2753.
[623] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p10.
[624] Andrea S. Ciullo et al., "A Supernumerary Soft Robotic Hand-Arm System for Improving Worker Ergonomics," Biosystems & Biorobotics (Cham: Springer International Publishing).

As discussed earlier in the chapter, Ifran Hussain and Dominic Prattichizio published a book by Springer under their 'Biosystems & Biorobotics series, Volume 26' called *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs.*[625]. Their book discusses most of the innovations mentioned here, but is primarily concerned with their own Sixth Finger prototypes or those of their collaborators. In collaboration with Gionnata Salvietti, their third chapter, 'Compensating Hand Function in Chronic Stroke Patients Through the Supernumerary Robotic Finger'[626], fails to fully showcase the work undertaken in this field. One important prototype that was missed is reviewed in this dissertation and shows the need for various third-thumbs to address the complexity that comes with a high level of spinal cord injury effects, which exceeds lost arm function. Lee et al. published a paper called 'Assistive Supernumerary Grasping[627] with the Back of the Hand' in 2021 developed at UC Berkeley Engineering. This prototype was intended for C6/C7 spinal cord injuries because people with this type of Cervical injury 'lose voluntary flexion of the wrist and finger'[628] as the injury has occurred at a high point on the spinal cord.

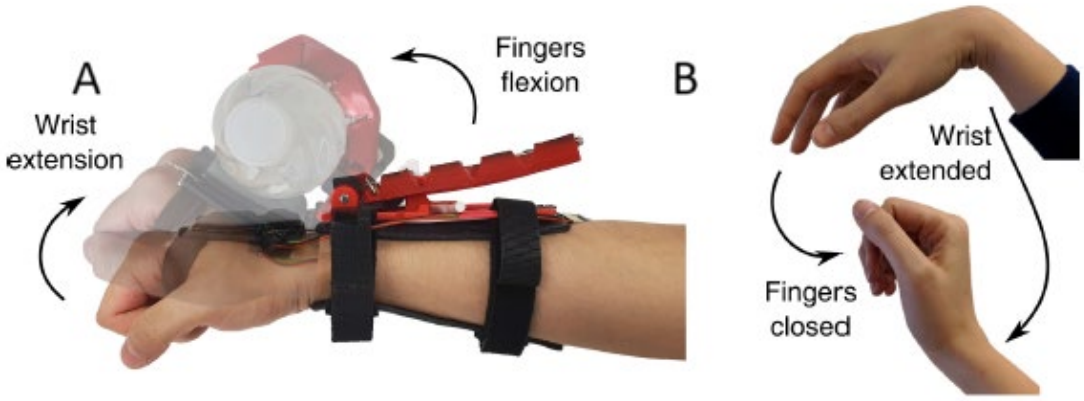

Figure 36 - (a) The Dorsal Grasper includes a set of soft, flexible fingers and an artificial palm on the dorsal part of the hand. Here, a water bottle is grasped using both the operator's wrist extension and artificial finger flexion. (b) A tenodesis demonstration shows active wrist extension elicits passive finger flexion. Taken from Lee et al.[629]

Seen in Figure 35, this SRF called the Dorsal Grasper, is a device that takes into account the pathology of the hand, allowing the grasp of larger objects whilst not impeding the hand for other purposes such as 'palmer tenodesis grasping or use of specialised tools'[630]. The ontology of the

[625] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*.
[626] G. Salvietti et al., "Compensating Hand Function in Chronic Stroke Patients Through the Robotic Sixth Finger," *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 25, no. 2 (2017), https://doi.org/10.1109/TNSRE.2016.2529684.
[627] J. Lee et al., "Assistive supernumerary grasping with the back of the hand" (paper presented at the 2021 IEEE International Conference on Robotics and Automation (ICRA), 30 May-5 June 2021 2021).
[628] Lee et al., "Assistive supernumerary grasping with the back of the hand," p6154.
[629] Lee et al., "Assistive supernumerary grasping with the back of the hand," p6154 Figure 1.
[630] Lee et al., "Assistive supernumerary grasping with the back of the hand," p6155.

structures of this finger builds on the projects of Wu and Asada[631] and that of Hussain et al.[632]. Both projects have already been discussed.

It is important to note that different prototype projects discussed in this review, 'especially for hand rehabilitation and function recovery'[633], are intended for different phases of the recovery, and this is especially true for the crucial period of the first few months after strokes, for example. According to Salvietti et al., 'only a few works [projects] target the robotic compensation of hand function in the latter phase of rehabilitation.'[634] This means that designs sit on a spectrum that functions as rehabilitation devices. As the time from injury increases, they tend to move towards SRF designs, serving as assistive devices for ADLs or as simple ADL tools. An example of this progression in design function is seen in the development of the Robotic Sixth Finger, one of the first SRFs reviewed, which was developed by Ifran Hussain and Domenico Prattichizzo between 2015 and 2017 in various iterative versions, as previously discussed.

Conclusion

Through this comprehensive examination of SRF technologies over the past one and a half decades, we have witnessed remarkable innovations in design, control interfaces, and feedback systems. From Prattichizzo's pioneering Sixth Finger to Clode's aesthetically designed Third Thumb, each artifact represents a unique approach to augmenting human capability through technological extension. What emerges from this review is not merely a technical landscape but an ontological frontier where subjectivity intersects with the technics of augmentation in profound ways.

The evolution of SRF designs—from rigid mechanical structures toward flexible, compliant systems—mirrors a deeper understanding that true augmentation must consider not only functional capabilities but also the embodied experience of the user. The most promising innovations acknowledge that a sixth finger is not merely an appendage but a potential transformation of body schema, requiring thoughtful integration with neural pathways and existing cognitive frameworks.

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[631] Wu and Asada, "“Hold-and-manipulate” with a single hand being assisted by wearable extra fingers."
[632] Hussain et al., "The Soft-SixthFinger: a Wearable EMG Controlled Robotic Extra-Finger for Grasp Compensation in Chronic Stroke Patients."
[633] Gionata Salvietti, Irfan Hussain, and Domenico Prattichizzo, "The Robotic Sixth Finger: A Wearable Compensatory Tool to Regain Grasping Capabilities in Paretic Hands," Springer Proceedings in Advanced Robotics (Cham: Springer International Publishing, 2017), p424.
[634] Salvietti, Hussain, and Prattichizzo, "The Robotic Sixth Finger: A Wearable Compensatory Tool to Regain Grasping Capabilities in Paretic Hands," p424.

As we move forward, the critical question becomes not whether we can technologically augment the human hand but how these augmentations will transform our subjectivity—our sense of self, our relationship to tools, and ultimately, our social and political existence. The most visionary researchers in this field have begun to recognise that the field of SRF technics represents not just a technical challenge but an opportunity to reimagine the boundaries of the human body and its capacities within Integrated World Capitalism's (IWC's) productivity-driven paradigm.

The future of SRF development lies not just in overcoming mechanical and computational obstacles, but in creating interfaces and experiences that enable these technologies to become true extensions of human subjectivity, rather than mere tools. This transformation will require continued collaboration across disciplines, including engineering, neuroscience, philosophy, the arts, and social sciences.

Chapter 4A - Transversality: breaking away from the traditional forms of analysis

Introduction to Chapter 4 series (A–E)

The following five chapters will explore the concepts of subjectivity by Suely Rolnik and Félix Guattari, relating them to subjectivity in the context of the technical particularities of Supernumerary Robotic Fingers (SRFs). This approach combines two distinct fields to develop a critique and establish a foundation for knowledge. Herein, the explication and deployment of the image of subjectivity emergent in the *Molecular Revolution in Brazil* will particularly focus on the thematics of *transversality,* so central to understanding Rolnik and Guattari. Transversality is a type of psychoanalytical position where relationships to ideas and beliefs are presented as diagonal lines of communication and action that cut across institutional boundaries, social fields, and knowledge domains to enable new forms of collective subjectivity (while maintaining their elemental properities) and political agency. The first five chapters will simultaneously explore and activate this conceptual quality through the various themes introduced in Chapter 2 of *schizoanalysis*, including the *machinic, group therapy (the process of singularization),* the *molecular revolution* and creativity, as well as the concept of *new smoothness,* which is explored sequentially. Although transversality permeates all of these themes, the instance of transversality and its operation will also be discussed separately. Attached to these themes above are also several subthematics, such as the meaning of *identity*, *individuation* (or *serialised subjectivity*), *minorities and autonomy*, *desire*, *the unconscious*, *the analytical process of singularization* (which is on the opposing scale of individuation)*, the discourse of semiotics* and its impact on the unconscious, *the rhizome, micropolitics (micro and molar), Marxism* (which includes the concept of *Intergarted World Capitalism*), *collective assemblages of enunciation* and resistance. These subthemes, which continually emerge and re-emerge, will also be addressed either intertextually or separately throughout Chapter 4 (series A-E).

Introduction to Chapter 4A

This dissertation aims to bring together two disparate domains or discourses. The following chapter further explores each theoretical conceptual quality in greater depth than it was introduced in Chapter 2. It shall also elaborate on the technological particularities discussed in Chapter 3 in more detail and individually. It achieves this by examining the theory of subjectivity and then investigating

the technical particularity of SRFs, before finally intersecting the two to uncover the complexity of their synthesis.

In the introduction of Guattari's book *Molecular Revolution Psychiatry and Politics* (2008) David Cooper suggests that during the 1960s, Guattari was a practicing psychoanalyst at 'La Borde psychiatric clinic south of Paris, where he elaborated his idea of "institutional analysis" as a methodological critique of "institutional psychotherapy"'[635]. Key aspects of Guattari's views on psychoanalysis are captured in his books and essays, most of which were written in French and were much later translated into English by others. In addition, he wrote books with Gilles Deleuze, in which Guattari deployed several ideas he had developed, including *schizoanalysis*, *institutional psychotherapy*, the critique of *Oedipalization*, *desiring machines*, and transversality. Transversality is a complex and central theme behind the book *Molecular Revolution in Brazil*. For Guattari, transversality is the crossroads of many diverse and heterogeneous assemblages that construct subjectivity.[636] Guattari is wary of using his ideas as concepts[637], so I shall try to avoid calling them that as much as possible, even though it is hard at times. Instead, I may use the term *ideas*. As we shall see, so many of his ideas on subjectivity, some of which I mentioned above and many more to come, are interlinked and shall also be explored in the following chapters on transversality.

In this chapter (4A), I will introduce Guattari's complex and broad definition of transversality through its relationship with other concepts closely tied to this idea. I shall first explore Guattari's break with traditional concepts of analysis, primarily through the concept of *schizoanalysis* and relate how his critique of *transference* laid the groundwork for transversality. I shall then explain some related ideas to transversality that make it so unique and its elaborate on its *semiotic* agency. I shall extend the exploration of Guattari's ideas of the *rhizome* and his understanding of *minoritarian subjectivity*, which relates to the *rhizome*. This is followed by ideas in the field of SRF that relate to minorities, such as those with polydactyly and those who wish to augment their bodies. I will attempt to uncover these subtexts in the research on SRFs. These ideas come together in the final third of this chapter by concentrating on the various psychoanalytical dynamics that lead to bias and discrimination in broader society towards minorities who have supernumerary fingers, be they augmented or congenital. Then, I examine the field and the paradigm of an augmented third-thumb by first looking at how researchers view polydactyly, which is characterised by a genetic extra thumb or supernumerary finger. I relate the *minoritarian subjectivity* of the individual with polydactyly to

[635] Félix Guattari, *Molecular revolution : psychiatry and politics*, Peregrine books, (Harmondsworth, Middlesex, England ;: Penguin, 1984), p2.
[636] Guattari, *Molecular Revolution in Brazil*, 1, p397.
[637] Guattari, *Molecular Revolution in Brazil*, 1, p336.

the proposition provided by particular research groups that use polydactyly to expand our understanding of augmentation via transversality. This leads us to understand the operation of self-determination and autonomy that can emerge from a Guattarian analysis of subjectivity, allowing minoritarian groups to resist normative ideas of the body. I approach this through a speculative and theoretical lens, considering the field of SRF in light of Guattari's conceptual qualities of transversality and what I term *techno-subjectivity*. Techno-subjectivity is the process that enables free, flourishing individuals (subjectivity) through their resistance and unrelenting capacity to buck habitual ideas of body normativity using technologies. This, in turn, leads to considerations of how social revolutions emerge from changing approaches to understanding the field of SRF, which may serve as seeds for more open and free societies, as well as for the progression of evolutionary changes.

Schizoanalysis

Schizoanalysis is a critical examination of psychoanalysis. Schizoanalysis seeks to expand analysis to encompass the collective and social dimensions, thereby gaining a deeper understanding of the larger social and political forces that influence groups and institutions. Guattari says that 'schizoanalysis is something that moves completely outside the psychoanalytic' field as such.[638] Guattari seeks to integrate psychoanalytic concepts with broader social and cultural circumstances, challenging the narrow focus on the individual psyche (found in psychoanalysis). He advises '[t]he field of schizoanalysis really goes far beyond the area that psychoanalysts consider to be theirs'.[639] Guattari emphasises understanding the shared psyche's impact on the social and political environment, and vice versa, which is reflected in groups and institutions. Rolnik explains, describing Guattari's vision in this way: 'the exercise of [schizo]analysis as this flair for the politico-libidinal economy of social life in its various nuances—in other words, as the exercise of micropolitics'.[640] The *micro* of the micropolitics that Rolnik refers to can be understood as the politics of the self—of subjectivity—of the individual and their collective relations through points of resistance. This is not an attempt by Guattari at a collective psychosocial experiment, or as Guattari refers to it as, 'psychosociological intervention:'[641] but rather to gain specific insights into subjectivity through the cross-analytical lens of socio-political thought and the extension and abstraction of psychoanalysis synchronously. Guattari seeks to understand the impact of intrinsic and extrinsic factors that shape

[638] Guattari, *Molecular Revolution in Brazil*, 1, p390.
[639] Guattari, *Molecular Revolution in Brazil*, 1, p395.
[640] Guattari, *Molecular Revolution in Brazil*, 1, p431.
[641] Guattari, *Molecular Revolution in Brazil*, 1, p336.

the individual, rather than relying on ideas of subjectivity based on institutional norms and simple psychoanalytical models.[642] In turn, the schizoanalysis involves breaking down the meaning of such ideas and understanding their impact on the subject. Guattari gives us some clues about the meanings he is seeking by targeting as 'a "regime of signs"—the regime of the signifier—and proposes the consideration of other semiotic dimensions.'[643] He is searching for meaning through these systems of signification, which he posits as the central mechanism of subjectivity. This approach provides a more holistic understanding of the subject and its detailed, contextual realities that are immediately apparent, bridged by language and signs of referents—things like class, race, and gender. Guattari calls this an instance of '*déjà là*',[644] the realities of life that exist right before us, right in our view.

Guattari is attempting to move away from very structured models of psychoanalysis that render typified symbolic outcomes predicated on traditional methods. These modelled methods produce typified outcomes centred on strict and structured ways of understanding subjectivity based on *transference* and *interpretation*. Transference and interpretation are based on very isolated concepts of how we understand subjectivity and the functional reading of the psyche. Typically, this is known as metapsychology and is formed from concepts derived from Lacanian and Freudian theories.[645] Transference might be thought of as a projection of mental images of particular personality traits of a primary caregiver, often imprinted very early in childhood, onto others. Interpretation, in a simple sense, is the analysis via the dynamics between the child and its parents, often referring to the 'Oedipal triangulation [Oedipalisation], a certain figure of submission to the dominant values with the castration complex'[646]. Schizoanalysis is a departure from both. In their book *Molecular Revolution in Brazil*, Suely Rolnik and Guattari describe schizoanalysis in this way:

> Whereas psychoanalysis set out from a model of the psyche based on a study of neuroses, focusing on the person and identifications and working on the basis of transference and interpretation, schizoanalysis takes its inspiration instead from research into psychosis; it refuses to reduce desire to personological systems; it denies that there is any efficacy whatever in transference and interpretation.[647]

[642] Félix Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, trans. Ames Hodges (United States of America: Semiotext(e), 2015), p111.
[643] Guattari, *Molecular Revolution in Brazil*, 1, p390.
[644] Guattari, *Molecular Revolution in Brazil*, 1, p252.
[645] Guattari, *Molecular Revolution in Brazil*, 1, p398.
[646] Guattari, *Molecular Revolution in Brazil*, 1, p304.
[647] Guattari, *Molecular Revolution in Brazil*, 1, p470.

Where transference functions on dialectic and sequential analysis that Freud developed in particular reference to neuroses, psychosis would become the basis of schizoanalysis and is a more elusive mixed level of comprehension of issues engulfing the subject. Schizoanalysis requires insights from disparate analyses, capturing the smallest grains of insight, to construct and make sense of the atypical enunciations that are sometimes harder and more complex to decipher than the models found in transference. Guattari suggests it is the 'transformations that are established simultaneously between the most heterogeneous domains that one could conceive'.[648] Guattari supports his argument by further saying: '[i]t presupposes various modalities of "transversality" between those domains.'[649] This reference by Guattari is our first indication of transversality and its connection to schizoanalysis. It places transversality commensurate with something greater than its parts in the complex mixture of its heterogeneous elements.

What is being developed in Rolnik's earlier critique of transference and interpretation is a description that encapsulates an explanation of Guattari's aversion to transference and interpretation as the primary tool to decipher the psyche's conflicts and desires. By adding to this an understanding of the 'theory of the unconscious […] conceived as replacing the Freudian "complex"', it becomes a way of understanding interpersonal and intrapersonal relations systems.[650] For Guattari, the ability to pick up on the threats of the discordant utterances from the non-sense in psychosis (which emanates from the unconscious), he views this as a valuable tool in helping reconstruct the shattered subject. It informs the links to the broader social and political scrutiny in the schizoanalysis operating within the milieu that crosses the borders between the unconscious and social realities.

Schizoanalysis and desire

Earlier, I quoted Guattari as saying, 'schizoanalysis takes its inspiration instead from research into psychosis; it refuses to reduce desire to personological systems'.[651] Let me briefly explain how Guattari conceives of the idea of desire. For Guattari, desire is any feeling or intuition that expresses the authentic content of the subject, not just sexual desire.[652] Guattari says in his opening to 'Emotion, Energy, Body, Sex' in Chapter 5 of *Molecular Revolution in Brazil* that he and his

[648] Guattari, *Molecular Revolution in Brazil*, 1, p397.
[649] Guattari, *Molecular Revolution in Brazil*, 1, p397.
[650] Guattari, *Molecular Revolution in Brazil*, 1, p463.
[651] Guattari, *Molecular Revolution in Brazil*, 1, p470.
[652] These are ideas that come from Chapter 4, Desire and History, and Chapter 6, Love, Territories of Desire and a New Smoothness from the book written by Rolnik and Guattari ,Guattari, *Molecular Revolution in Brazil*, 1, p291-402,13-26.

collaborator Deleuze prefer to speak of desire in broader ways, not reducing desire to sexual desire, but rather all highly dynamic forces that express the subject's multivariant resonances and intensities. He believes that:

> Gilles Deleuze and I [he] have adopted the position of practically not speaking of sexuality, and instead speaking of desire, it's because we consider that the problems of life and creation are never reducible to physiological functions, reproductive functions, to some particular dimension of the body.[653]

Guattari also says, '*I think it is much more useful to work toward a theory that considers desire as being immediately of the nature of highly differentiated and elaborated machinic systems.*'[654] Guattari depersonalises desire and displaces it from the traditional Freudian context by rendering desire a highly differentiated and *machinic* complex abstract paradigm. Sexual desire is referenced heavily in the analysis of transference and interpretation, for example, in the Oedipal complex. This is a concrete representation of desire as something simplistic. The alternative, highly differentiated and ontological desire is key to understanding the motion behind transversality as suggested by Guattari. If we think of transversality as a net connected to a vector that flies and catches the multiplicity of the heterogeneous constellations in space, then desire is its engine. The metaphor of the machine or *machinic* evokes the ubiquitous, de-individualised, catalytic nature of desire that spontaneously emerges and re-emerges with contingencies for many connections. As Guattari tells us, he and his collaborator, Deleuze, prefer to speak in terms that express the extrapersonal (Forces/processes happening *within* the individual psyche) and infrapersonal (Forces/processes happening *beyond* the individual, in collective/social assemblages) nature of desire, using their concept of *desiring machines* to drive home the point of the variations in their concept. 'Desiring machines'[655] control the flow and connection between other machines, which is determined by networks and systems of alliances that precede transversality.[656] Guattari reasons that desire brings together life's potential and constructs subjectivity.[657] He adds that desire takes many forms, often instinctual references arising from the unconscious. Rolnik describes it by defining desire as 'a taste for living, a will to construct the world in which we find ourselves, and the establishment of devices to change types of society and types of values that are not ours.'[658] Desire

[653] Guattari, *Molecular Revolution in Brazil*, 1, p403.
[654] Guattari, *Molecular Revolution in Brazil*, 1, p403.
[655] Guattari, *Molecular Revolution in Brazil*, 1, p465.
[656] Guattari, *Molecular Revolution in Brazil*, 1, p408, 12.
[657] Desire is a major theme throughout the book Guattari, *Molecular Revolution in Brazil*, 1, 15,223,48. Guattari and Rolnik even dedicate two whole chapters to it: in Chapter 4, Desire and History, and, Chapter 6, Love Territories of Desire and a New Smoothness.
[658] Guattari, *Molecular Revolution in Brazil*, 1, p23.

and the unconscious are not considered a super-structural relation to the body but an inseparable, intertwined dynamic. Still, this relationship of the unconscious and desire produces the flows of speech, semiotics, and responses to affect found when transversal relations. That is, relations with other unfamiliar territories that allow us to open our minds in ways that enable us to construct ourselves and gain control in the development of a flourishing *autonomous* subjectivity. In Chapter 2 I defined Guattarian autonomy as the capacity to follow lines of flight that deterritorialise us through encounters with otherness, generating new affective territories that exist beyond the capitalist capture of desire and the repetitive cycles of attachment and detachment. This transformation allows a type of mastery of creativity and the processes of becoming unique. Desire permeates everything. The processes that involve desire and affect through our bodies enable interaction, reconfiguration, and permutation in ways of existence and living. Concrete examples of the impact of desire upon the transformation of sensibilities enable the very affects of art and creative pursuits that can transform us and forever change our views. These processes engender and draw out desire, being part of a system of creative, flourishing relations that bloom in the domains of intersubjectivity. Guattari considers these processes to originate from a flat system, characterised by flat circuitry with no hierarchy, which is processual and the precursor to transversality[659] , namely, that of the machinic.

Schizoanalysis and semiotics

Guattari wants us to note that the underlying analysis related to schizoanalytic therapies doesn't happen '*ex nihilo*'.[660] Rather, the analyst who participates in the process of schizoanalysis is reading the fine thread of signs, and their mastery as analysts resides in their ability to decipher them. In describing schizoanalysis in *Molecular Revolution in Brazil*, Guattari and Rolnik refer to an idea proposed by Deleuze and Guattari in their book *Anti-Oedipus* (1972). Guattari suggests that schizoanalysis 'sees psychoanalysis as a "regime of signs"—the regime of the signifier—and proposes the consideration of other semiotic dimensions."[661] This 'other semiotic dimension' contains all means, processes and signposts useful in analysis, even in the broader reading of transferential interpretations. It is also the case that Guattari continues to say that the components of transversality cannot be understood within the limited 'treasure-trove'[662] of Freudian and Lacanian 'theories like that of the signifier'[663], with particular reference to Oedipal triangulation and

[659] Guattari, *Molecular Revolution in Brazil*, 1, p177.
[660] Guattari, *Molecular Revolution in Brazil*, 1, p317.
[661] Guattari, *Molecular Revolution in Brazil*, 1, p390.
[662] Guattari, *Molecular Revolution in Brazil*, 1, 394.
[663] Guattari, *Molecular Revolution in Brazil*, 1, p391.

mathemes.[664] Just as schizoanalysis opened psychoanalysis to the broader and more complex realm of the socio, transversality presupposes all the touchpoints of environmental and contextual dimensions that exceed transference. Transversality proposes the opening of transference into the broader mode of connections. It includes the appraisal of all impacts and contingencies of expression derived from groups and institutions, as well as their analytical reflections. These reflections cast a wide net over our understanding and its effects on subjectivity.

Through this abstraction, schizoanalysis permits Guattari to recognise the drivers of social, political, and economic flows as systems of desire driven by machines seeking to connect with them and the groups and institutions that influence them. In this way, schizoanalysis becomes a system that provides a mastery of reading signs and significations. This movement, where schizoanalysis as an idea helps inform analysis, also facilitated Guattari's similar transition from transference to transversality.[665] Transversality is a dynamic that alters the status quo to mobilise the diverse flow of heterogeneous resonances, unleashing desire to promote subjectivity that is both faithfully unique and socially interconnected among individuals. Although transversality precedes schizoanalysis in the dynamic of subject formation and subjectivity, it reflects the same departure and transition from traditional modes of analysis to a wider contextual field.

Transference

Before turning to transversality, we must first understand how he arrived at this point. Therefore, reflecting on his critique of transference as the starting point of the concept of transversality is necessary. What is transference? We have already touched on this. The therapeutic and strict definition of transference is the expression of certain childhood experiences, often arising from internal conflict with the super-ego in maturity, which are suppressed and unconsciously projected onto the people we meet later in life.[666] Levy and Scala defined transference in simple terms as a projection of a mental image of particular personality traits of a primary caregiver, often imprinted very early in childhood, onto others.[667] One way of thinking about this is that patients view authority figures, such as their analyst, as a representation of their father, behaving and soliciting behaviours that emulate aspects of their past familial relationships. When the solicitation is successful and the

[664] Guattari, *Molecular Revolution in Brazil*, 1, p391.
[665] Guattari, *Molecular Revolution in Brazil*, 1, p343-47.
[666] Heinrich Racker, *Transference and counter-transference* (Routledge, 2018), p71-78.
[667] This is taken from an earlier paper by Kenneth Levy in 2009 cited by Kenneth N. Levy and J. Wesley Scala, "Transference, Transference Interpretations, and Transference-Focused Psychotherapies," *Psychotherapy (Chicago, Ill.)* 49, no. 3 (2012): p392, https://doi.org/10.1037/a0029371.

predicted response is elicited, this is known as 'countertransference'.[668] These representational aspects that Levy and Scala speak of can manifest in behaviours that reflect feelings of love, hatred, conflict, and argumentation, projecting the patient's state of mind towards the father onto the analyst. Should that solicitation be successful, that analyst may fall into a similar trap and respond in ways that reflect the father's behaviours. The analyst's response that mimics the father's behaviour patterns can sometimes be attributed to the dynamics of 'countertransferences'.[669]

In his well-known book on psychoanalytic techniques, *Transference and Countertransference*, first published in 1968, the psychiatrist Heinrich Racker defines Freud's transference in this way:

> He [Freud] gives two causes for transference in general, (*a*) the fact that every person acquires in childhood certain characteristic ways of 'living his love', from which arise patterns regularly repeated throughout his life, and (*b*) the fact that lack of libidinal satisfaction, caused by unconscious fixations, creates a libidinal need and expectancy which is directed towards the persons he meets. The special part played by transference in psychoanalytic treatment is to be explained, according to Freud, by its relation to resistance. The transference becomes so intense and long-lasting because it serves the resistance; the analysand reproduces and acts upon his unconscious impulses in order not to 'remember' them.[670]

Therefore, according to Racker, Freud's transference principle is not only repeating past behaviours affixed due to some 'lack of libidinal satisfaction' but also because of an analysands' 'relation to resistance'[671] or not wanting to remember why he repeats the pattern of behaviour when this conflict was instigated. In this conundrum, it is better to transfer one's thoughts to someone else. Central to this idea is the Oedipalisation of family relations as a constantly resistant pattern which is said to limit one's behaviour across all relations while constantly fearing the castration complex (i.e. fearing that one might be 'cut off' - the symbolic castration of oneself because of desires for mommy or daddy). The resistance here is what led Oedipus to gouge out his eyes (it's better not to see what's going on). The Oedipal project is particularly infantilising for the subject. Guattari discusses that:

> for me, it really arises as a question of transference, that is, as a mortal trap. We could say that whenever a transference occurs, a situation of alienation has been established, which probably functions as an obstacle to the real analytic processes.[672]

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[668] Racker, *Transference and counter-transference*, p18.
[669] Levy and Scala, "Transference, Transference Interpretations, and Transference-Focused Psychotherapies," p392.
[670] Racker, *Transference and counter-transference*, p71.
[671] Racker, *Transference and counter-transference*, p71.
[672] Guattari, *Molecular Revolution in Brazil*, 1, p385.

The alienation referred to by Guattari is particularly damaging to subjectivity. Sitting in a room, the analyst and the analysand revisit old ground in the family relations, much like an in vitro experiment. In a conversation, Rolnik and Guattari summarise it in the following way: 'transference would function as a kind of black hole' of entrapment 'that engulfs all the potentialities of semiotic productivity, whatever its nature may be'.[673] Talking is a form of semiotic performance that, in psychoanalysis, contains the production of utterances that allow the analyst to decipher the mental references of the analysand. Therefore, semiology and, to a lesser degree, the pragmatics of significance are important fulcrums that Guattari uses to construct and reconstruct his thought on subjectivity. Schizoanalysis seeks to do this extrinsically, outside the therapeutic setting, supported by the underlying structure of heterogeneous connections that allow the flows of ideas core to transversality.

The semiology of transference (the way transference is conveyed)

Since transference is expressed through language, it is essential to address the role of semiology and semiotics in subjectivity. I will briefly discuss its significance here and elaborate on it in greater detail in the following chapters on the therapeutics of groups, specifically in Chapters 4B and 4C.

Guattari suggests that deciphering semiotics is crucial to any analysis, which is generally an operative dynamic keyed in unconscious discourse between the subject and groups and institutions, not just between analyst and analysand.[674] Guattari says signs and signifiers of the industrial complex piggyback onto particular signifying logics within social frameworks, making themselves more visible when we analyse subjectivity through groups and institutions.[675] Because group and institutional pronouncements can be better understood in light of the biases and structures that shape their messages. The process of imposing capitalist values on the psyche is what Guattari calls 'capitalistic subjectivation', which can also be viewed as a transferential projection of the ideal values of an economy of desire based on money.[676] These enunciations of the values of capitalist subjectivation typically occur via groups and institutions. I imagine their analytical potency lies in the information that can be uncovered through therapeutic discourse, except that its elucidations are much more expansive and reference greater societal issues than the transferential model could ever manage. In

[673] Guattari, *Molecular Revolution in Brazil*, 1, p386.
[674] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p79-81.
[675] Guattari, *Molecular revolution : psychiatry and politics*, p13.
[676] Guattari, *Molecular Revolution in Brazil*, 1, p209.

his book *Psychoanalysis and Transversality,* first published in 1972, in his essay 'The Transference', Guattari writes,

> J. [Jacques] Schotte was right in highlighting the nature of signifying operations that allow us to identify transferential phenomena with those of speech and language. This ought to help us clarify the question of the transference outside of the strict field of psychoanalytic experience, that is to say, of the transference as it manifests itself in the group or institution.[677]

Thus, Guattari, following Schotte (and Lacan[678]), suggests that language is a key social dynamic and a bridge to understanding subjectivity. He is expanding Schotte's ideas on the links between transference and the broader field of language to connect analysis to wider groups and institutions, where the possibility for meaning may be more easily apprehended and deciphered.[679]

The concepts of *groups*, organisations, and institutions hold a special meaning for Guattari within the wider socio-political setting because they encompass the problematic and struggles for semiotic exchanges that shape our understanding of subjectivity.[680] The significance of *groups* and institutions, and their impact on transversality, will be explained in later chapters (discussed in detail in Chapter 4C). For now, groups and institutions can be considered stand-ins for the social frameworks that can be challenged through subjectivity to bring about change. It is worth noting what Guattari proclaims about subjectivity and groups when he suggests that:

> group's subjectivity "…production also is not only a particular production. Rather, it is always a certain social body, a *social subject*, which is active in a greater or sparser totality of branches of production. […] involving a whole correlate of phantasizing, and a whole aspect of social creativity which I have sought to sum up as "transversality".[681]

Hence, Guattari links group communication with the opportunity for change. Thus, the social body is in a state of creative force and functions to produce subjectivity that expresses ritornellos of expressions greater than the individual and its isolated person. This is related to another idea that will be explored in future chapters of this series, which looks at *assemblages of enunciation.* We can appreciate the relationships between groups and the expansion of transferential phenomena that

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[677] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, 76.
[678] Guattari, *Molecular Revolution in Brazil*, 1, p292.
[679] David Cooper describes in the Introduction to *Molecular Revolution Psychiatry and Politics* that Guattari doesn't hold the position of an '"antitheoretical"'.[679] Cooper suggests Guattari presents a new approach, a new 'theoretical activity that would avoid simplifying reduction to containing structures such as the dyadic and triadic situations of psychoanalysis (transference situation, Oedipal complex).' in Guattari, *Molecular revolution : psychiatry and politics*, p2. It is worth noting that Guattari did not affiliate himself with the anti-psychiatry movement.Guattari, *Molecular revolution : psychiatry and politics*, p45.
[680] Guattari gives example of the type of semiotic struggles that impact subjectivity by looking at political situations across the globe in Guattari, *Molecular Revolution in Brazil*, 1, p267-71.
[681] Guattari, *Molecular revolution : psychiatry and politics*, p26.

bring us to the threshold of understanding one of the main functions of Guattari's ideas on transversality, and thus it is how it holds the subject in a network of relationships that extends beyond the family and the analyst-analysand.

In the context of his experience observing the field of psychiatry, Guattari feels 'a systemic failure [by those providing treatment] to understand what is going on outside the hospital walls, a tendency to psychologise social problems' while not seeing the injustices and politics of the situation.[682] This is the critique of institutions he observes regarding their aims and treatment.[683] Guattari seeks to address reality at the point of social and political disjunctions and alienation through analysis, rather than merely 'psychologising' such problems. This is why a clinic like La Borde, where Guattari worked, opened its doors to the community in a way that allowed for non-hierarchical relations between patients, staff, and the village. Guattari did not want the 'architecture and urban configuration of the place to repeat the pattern of hierarchical transference'. [684,685]

Transversality

Unlike transference, the function of transversality examines all possible encounters with signs, thoughts, dreams, practices, and expressions—both conscious and unconscious—that flow through an individual's subjectivity to find alignments with their desires. The crisscrossing messages, qua transversality, open groups' or institutions' utterances to diversity and new ideas, releasing the potential for growth in the individual. Transversality positions itself at all levels of communication, accounting for and reflecting the broader social dynamics of messaging between groups and institutions, thereby breaking out of the 'encirclement of […] four walls' of transference, as described by Guattari.[686] In addressing Guattari's works in the preface to *Psychoanalysis and Transversality: Texts and Interview 1955-1971,* Deleuze says, transversality 'deploys a latent desire coextensive with the social field entailing ruptures in causality and the emergence of singularities, sticking points as well as leaks.'[687] Deleuze highlights Guattari's commitment to the indices of transversality that arise ideally in free and dynamic societies, which give way to 'ruptures' and 'leaks'

[682] Guattari, *Molecular revolution : psychiatry and politics*, p7.
[683] Guattari, *Molecular revolution : psychiatry and politics*, p11.
[684] Chris L Smith, *Tranvsersailty Lecture 10* (University of Sydney2024).
[685] Guattari, *Molecular revolution : psychiatry and politics*, p103.
[686] Guattari, *Molecular Revolution in Brazil*, 1, p387.
[687] In the section Preface: Three Group-Related Problems written by Deleuze in the book by Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p8.

from normative agendas, moving us beyond those entrenched (mommy-daddy) models of transference. Beyond the polity of mommy-daddy-castration paradigms that capital uses to frighten the individual into adhering to norms. Deleuze describes Guattari's search for traces of *singularity* or the process of *singularization*[688] (discussed in Chapter 2), as well as the unique subjectivity of self-organisation, self-articulation, and the unique characteristics that affect flourishing subjectivity. These characteristics distinguish divergences and are the emergence of new connections through 'ruptures' discovered in analysing the subject within the context of groups and institutions.[689] The ruptures and leaks are the passages that allow subjectivity to flourish in all directions within the contexts of the *rhizomatic* (relatedness) and transversal connection. They constitute identifying and expressing the desires that make us different (outside the family context).

Guattari and Rolnik formally introduce us to the word transversality in the book *Molecular Revolution in Brazil,* in a sub-section titled 'Minorities and Rhizomes'.[690] Although Guattari has addressed interrelated issues that provoke the notion, this is the first time he uses the word explicitly in this book. This section recounts the conversation between an interlocutor (possibly an academic in the psych profession) and Guattari at the Federal University of Santa Catarina, Florianópolis, Brazil, on September 17, 1982. The discussion concerns itself with the question of how subjectivity is formed in free societies that express the perspectives of minoritarian and marginalised groups. The questioner asks Guattari to describe how he envisions the discourse between the groups and the subject (the individual), leading to new free and flourishing subjectivities. The questioner refers to the types of groups Guattari refers to 'that do not have centralised coordination, but that is also not spontaneous; forms in which power is diluted—in fact, everything that you [Guattari] call "rhizome"'?

In summary, Guattari argues that the processes of transversality enable the free operation of subjectivity through group dynamics.[691] The concept of the *rhizome* was briefly introduced in Chapter 2, as was the concept of groups and group theory. I would like to expand on this and connect it directly to its functions qua transverality. Together, these ideas will help us understand how these theoretical and conceptual qualities inform the conceptions of subjectivity that might shift the discourse surrounding the third-thumb.

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[688] Guattari, *Molecular Revolution in Brazil*, 1, p23,31.
[689] Guattari, *Molecular revolution : psychiatry and politics*, p2.
[690] Minorites and Rhizomes, a subheading under the section Minorities: The Becoming of society in the book by Guattari, *Molecular Revolution in Brazil*, 1, p174-78.
[691] Minorites and Rhizomes, a subheading under the section Minorities: The Becoming of society in the book by Guattari, *Molecular Revolution in Brazil*, 1, p174-78.

The rhizome

The *rhizome* at the centre of the questioner's mind is another important idea of Deleuze and Guattari that helps us think about transversality. If desire is the engine of transversality, then the rhizome is its pathway to realising multiplicity and diversity.

The rhizome is a complex idea. It is an emancipatory pathway system that breaks free from and escapes from dominant hegemonic organisation systems, much like Deleuze's description of ruptures and leaks. Vis-à-vis transversality, the rhizome shapes the assemblages that constitute and gather into subjectivity. The rhizome is a central theme in Deleuze and Guattari's thoughts on subjectivity. Simply put, the idea of the rhizome represents an anti-hierarchical approach to the syndication of connections, incorporating complex yet flat structures of heterogeneous relational formations or assemblages.

To visualise this, we can contrast how a tree is organised compared to how the rhizomes of grass might grow. When we think of a tree, it stands as a single branching logic, and Guattari sees its structure as a metaphor for arborescent logic. A single strand of logic from which categories unfold determines customary systems of reference, including how we imagine *normality*. Arborescent structures are associated with white, colonial, racialising, phallocentric (empirical) societies characterised by dominant capitalist hegemonies.

These arborescent characteristics of subjectivity delimit minoritarian subjectivities by throwing a wide net of categorisation over them. This net might encompass the logic of wealth, race, nationality, mental health, bodily categorisation, judgements of culture, and levels of primitivism, as well as other so-called cultural and social strata. Arborescent logic perpetuates a system of gradating individuals according to their divergence from this normative dogma. This highly structured form of social organisation is deeply rooted in societies. It arises from the strictly constructed, single-branching dendriform logic that mediates dominant socio-political and economic effects, which are often determined by capital. The same structures reinforce and reify norms, thereby perpetuating the systems at the heart of traditional psychoanalysis. They construct the normal family in a tight and regulated relationship with the world of labour and consumption.

A rhizome, on the other hand, is topologically diametric to arborescences. It is a self-generating logic that roots at intervals along the earth and shoots blades of grass as required to ensure the growth of new life. It is self-generating. You cannot trace an overall hierarchy of organisation in a rhizome, for it has a complex network that pays no respect to a foundation, origin, or garden borders.

Using this image of the rhizome, the Guattarian rhizomatic or rhizomic (used interchangeably) approach to psychoanalysis is attentive to the contingencies and complexities of the psyche's relations. It is not cognisant of relations of family alone or the psychoanalytical signs and significations that are readily modelled, off-the-shelf symbolic formats found in Freud and Lacan's metapsychology. Nor is it attentive to arborescent structures of society. The Guattarian rhizome traces connections between people and their relations to universal and global contingencies. It interlinks the various economies at play, between the political, libidinal, capital, environmental and social, in a harmonious yet complex intertwined way. It flourishes and fosters self-awareness, reflection, and regeneration at the very nodes of rhizomatic divergences and diversity, carefully building an unorganised but proficient system of relations that constructs the subject (the singularized individual).

Guattari's rhizomatic social structure establishes connections between individuals and groups through their intersecting desires while finding common ground for harmony. The rhizomatic subjectivity works to extend itself in a self-organised way, self-assembling to expand, redevelop, and emancipate flourishing individuals without adhering to the social codifications of strata that govern arborescent subjectivities. Rhizomatic subjectivity can connect across all strata of society in transversal relations to one another.

Rhizomatic minoritarian resistance informs subjectivities

The concept of rhizomatic minoritarian subjectivity was discussed briefly in Chapter 2. Here, I would like to expand this and directly correlate it with how it is underpinned by transversality. It may be helpful to revisit the exchange between Guattari and his interlocutor, which introduced Guattari's ideas of transversality and the rhizome. The interlocutor asks how subjectivities and groups can form relations from within (without external structures) to determine an autonomous notion of subjectivity. We know Guattari responds that transversality is key to unlocking intersubjective and intrasubjective relations—the unique discourse of the unconscious that permits the processes of autonomy. Guattari begins by explaining the 'alternative' nature of subjectivities and how groups are responsible for the functional dynamics of the rhizomatic expansion of the psyche. Guattari explains that he prioritises 'alternative'[692] subjectivities (also discussed in Chapter 2) by elucidating how this system brings about change at both the micro and macro levels. In the passage below, Guattari gives an example of how politically active minorities work towards configuring themselves in order to rise

[692] Guattari, *Molecular Revolution in Brazil*, 1, p177.

to the challenges of proclaiming their differences in their identities through the enunciation of desire as a sense of their 'alternativism'[693].

> When we want to characterise the "alternative" in terms of its processual character, it is merely a sign that we cannot sum it up in a theory, an ideology, or a practice. This does not mean that we make a vague combination, a vague syncretism. On the contrary, we work out an understanding of the singular positions in which each individual is situated, an understanding without paranoia, without projection, and without culpabilization. We do this precisely in order to make it possible, through this articulation, to develop a process of reflection and analysis, a complete *activity of metabolism of the change in the perception of situations,* which may possibly lead to alliances. The alliances, in this case, would be characterized by constituting systems of "transversality" whose criterion is the position of desire.[694]

To carefully break down this quote, I make the following points: Guattari speaks of the 'alliances' and 'desire', which will inevitably be the touchpoints for alternative subjectivities to connect unadulterated to their sense of otherness. By 'otherness', I think Guattari means other types of people, other subjective qualities, other views, other polities, otherness in sexuality, identity, race, classes, and so on. The alliances formed through new relations, connections, lines of communication, and messaging networks serve as a wayfinding tool for refreshing ways of interacting that divest from stagnant social models or mores, thereby creating a new, thriving society with autonomous individuals. These crisscrossing relationships are the type of analytic outcomes that are conceived in transversality. Transversality must be experienced by permitting the expressions of the subjective content, or as Guattari calls it, 'latent content'[695] - of group desire. We know that desire is key to subjectivity and connectivity. Once the groups can enunciate their desire, it transforms the personological frame of reference for the subject and triggers the rhizomatic and transversal awareness that conceived it. It's a kind of reawakening and a process of self-realisation about their situation. When Guattari refers to the alternative, he refers to minoritarians who resist in search of ways to safeguard and configure their subjectivities, unfettered by ideology, dogma, class, or social norms. This is a version of the *process of singularization*. The alternative emerges through this passage of resistance to ingrained normativity and alternates towards connection to the desires that promote its true expressions. Guattari suggests this is done 'without paranoia, without projection and without culpabilization'. I understand from this that Guattari means that subjectivities should be free from the judgment or blame arising when individuals depart from dominant systems that shape society. These ruptures and leaks, which are part of transversality, are

[693] Guattari, *Molecular Revolution in Brazil*, 1, 122.
[694] Guattari, *Molecular Revolution in Brazil*, 1, p177.
[695] Guattari, *Molecular revolution : psychiatry and politics*, p15.

the instigators that break from the 'processes of integration and normalisation'.[696] Guattari rejects both systems of capital and psychoanalysis for their coercion that imprints blame and shame on subjectivity when they try to express desires. Guattari rather finds ways to defuse the structures that might dictate subjectivity, allowing self-growth and self-determination. Guattari gives us an example. He explains his dismay with the psychoanalytical system used to indoctrinate the young in the education system from childhood, where psychologists and educators work to make ideal subjectivities.[697]

Transversality offers all the potentiality for subjectivity to break free from normativity. Patrick Ffrench's 2023 paper 'Guattari's Therapeutics: From Transference to Transversality' sums this up well by telling us, 'Transversality, in other words, is the therapeutic and existential precursor to the rhizome and to schizoanalysis.'[698] Ffrench asserts that transversality is the seed that plants the genesis of subjectivities seeking to break free, become unique, self-determined, and autonomous. Each subject can contribute to this revolution using the process of rhizomatics to bring about the social project of schizoanalysis.

Minoritarian SRF and the paradigm of a third-thumb

Minoritarian polydactyly, extra fingers

In the previous section, I made reference to Guattari's ideas on rhizomatic pathways to minoritarian resistance, which inform transversality in subjectivities, allowing them to become truer versions of themselves. Minoritarian acts of resistance to self-identify and remonstrate against the system that places those who sit outside body normativity into a subclass, bring about contact with transversal relations to society. It also places their development at the crossroads of independence and self-determination, pitting them against the forces of dominant subjectivity. One such minority in the field of SRF is a group of people with polydactyly. The projection of such minorities in medical and scientific research is problematic. I am specifically referring to the language of abject medical curiosity in the field of SRF discourse around those with polydactyly or those born with supernumerary fingers. This attitude may reflect the broader social context that minorities face.

[696] Guattari, *Molecular Revolution in Brazil*, 1, p52,180,370.
[697] Guattari, *Molecular Revolution in Brazil*, 1, p67,p142,p355.
[698] Patrick Ffrench, "Guattari's Therapeutics: From Transference to Transversality," *Deleuze and Guattari Studies* 17, no. 2 (2023): p219.

In the eyes of the medical community, polydactylism is regarded as '[c]ongenital deformities of the hand, […] a limb-related birth defect' because it 'has an incidence between 0.37 and 1.2 per 1000 live births, depending on race'. This is how the author of a 'Review of Polydactyly and its Inheritance: Connecting the Dots', Dalal K. Bubshait, MD, describes it.[699] In their search to explain this genetic phenomenon, authors such as Bubshait are quick to attribute such deviations from the norm to a syndromic genetic disorder that exceeds what is considered normal. The language used is depreciatory. Bubshait even goes as far as referring to polydactyly and its related medical issues as having an 'underlying illness process'.[700] Polydactyly in medicine is classified according to its deviation from the norm, including its deviation from the perspective of its genetic expressions. It appears to be focused on reductionist research, which aims to classify and simplify complexity and diversity. It is only seen for its 'different syndromic disorders'[701] as purely an undesirable consequence without intrinsic worth. The person with polydactyly is described with less regard, carelessly, through taxonomic euphemisms, and subjected to an identity that classifies them according to their polydactyly morphology (position of the polydactyly finger). Depending on the position of the redundant finger format, as shown in Figure 36, it is classified as either Pre-axial or Post-axial polydactyly. Bubshait further distinguishes these into subcategories according to many other associated conditions that discriminate the type of characteristics and 'related to disease phenotype, chromosome location, genetic mode, and related pathogenic genes'.[702] Not to mention, they include variations along 'ethnic lines'.[703] These medical features are indeed very clinical.

[699] Dalal K. Bubshait, "A review of polydactyly and its inheritance: Connecting the dots," *Medicine (Baltimore)* 101, no. 50 (2022): p1, https://doi.org/10.1097/MD.0000000000032060.
[700] Bubshait, "A review of polydactyly and its inheritance: Connecting the dots," p6.
[701] Bubshait, "A review of polydactyly and its inheritance: Connecting the dots," p1.
[702] Bubshait, "A review of polydactyly and its inheritance: Connecting the dots," p2.
[703] Bubshait, "A review of polydactyly and its inheritance: Connecting the dots," p1-6.

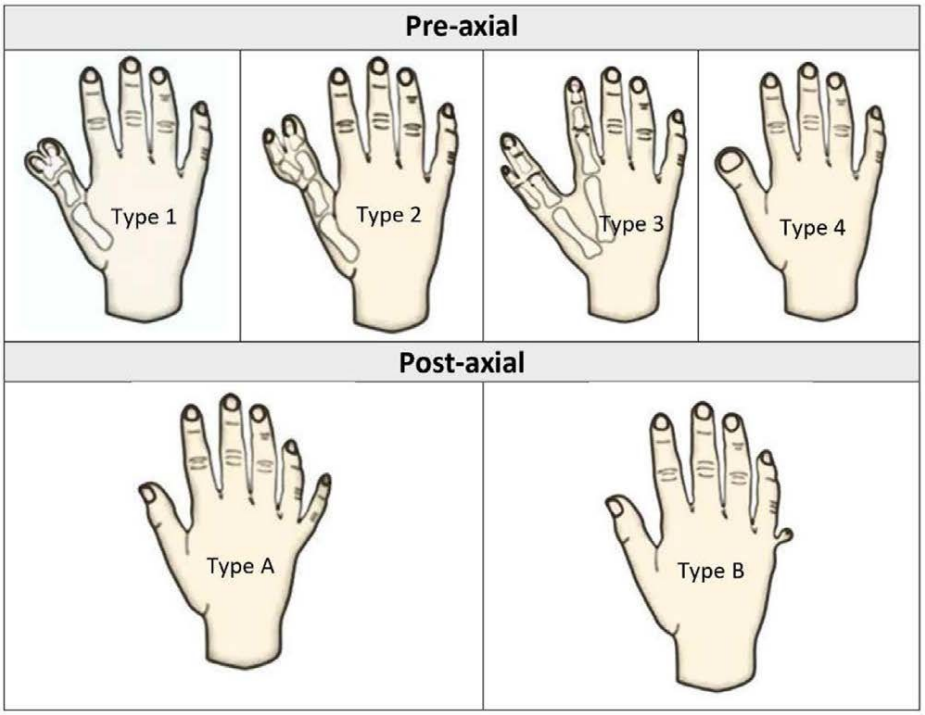

Figure 37-Phenotypic presentation of types of pre-axial polydactyly (PDD) and post-axial polydactyly (PAP) taken from the paper by Dala K Bubshait [704]

In Chapter 3, I discussed some aspects of the review by Prattichizzo et al. As a review of SRFs, this group of researchers stands out for their most insightful consideration of the broader implications of SRFs. Prattichizzo et al. venture beyond the simple descriptions of SRF projects, offering a unique perspective on subjectivity that other researchers have overlooked. Prattichizzo et al. reflect on the broader impacts of SRFs on specific aspects of the mind and subject formation, which also considers the future, including and valuing individuals with polydactyly without employing medico-pejorative language. They refer directly to the interesting conundrum of polydactyly, which informs and enhances our understanding of augmentation. Prattichizzo et al. believe in understanding the benefits of polydactyly and its contribution to SRF augmentation. Prattichizzo et al. present an exciting opportunity for understanding broader subjectivity and, ultimately, the potential contribution that this makes to those wishing to augment their capabilities with a third-thumb. They suggest:

> In individuals born with six-fingered hands, a rare genetic condition known as polydactyly, the control of the additional finger relies on an innate neural hardware that includes additional dedicated muscles and nerves, as well as dedicated representations at cortical level, either in the motor and sensory cortices. Such hardware allows polydactyly individuals to easily control over-physiological

[704] Bubshait, "A review of polydactyly and its inheritance: Connecting the dots," p4.

> degrees of freedom, to an extent that they can even improve some manipulation abilities without particular efforts.[705]

A distinct language shift in describing polydactyly helps us accept the values of polydactylies. It only takes such a small semiotic shift to do so. That is how Prattichizzo et al. reframe individuals with polydactyly as worthy because of their ability to inform us of the potential, opportunities, and prowess of augmentation. Prattichizzo et al. not only dispel the idea that polydactyly is a negative consequence of *congenital deformity* but also use the example to elucidate the concept of an SRF, benefiting the future of the human race. By examining what is missing in the structures of normal individuals, we can understand the additional services that individuals with polydactyly have to control and use their extra fingers, allowing normal individuals to learn from them. Their review discusses the current research on 'brain plasticity' and 'augmentation plasticity,' which refers to the brain's ability to respond and organise itself cortically to the demands of an additional finger.[706] Prattichizzo et al.'s research indicates that individuals with non-polydactyly, so-called normal brains that are not genetically wired and lacking the extra neurophysiological structures, can naturally adapt to the presence of an extra finger. Prattichizzo et al. research has shown a great propensity for five-fingered individuals 'to adopt [and adapt to having an extra finger] very quickly [to] new interactions with objects located with the peripersonal space'.[707] The concept of the 'peripersonal' space reminds us of Guattari's notion of a realm that surrounds the body, unlocking intersubjective and intrasubjective relations that reside in the unconscious desires.

Another group, Mehring et al., who published a paper, 'Augmented Manipulation Ability in Humans with Six-Fingered Hands' also demonstrate their intersubjective appreciation of polydactyly by suggesting that they possess the 'biomechanics and functionality' as a 'blueprint for the development of robotic hands'.[708] Using their assessments, Mehring et al. concluded the following:

> These superior abilities of our polydactyly subjects, which may be specific to the preaxial group of polydactyly and to the well-developed SF in our subjects, suggest to thoroughly evaluate the functionality of an SF in polydactyly infants before deciding on whether to remove it.[709]

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[705] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p14.
[706] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p15.
[707] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p15.
[708] C. Mehring et al., "Augmented manipulation ability in humans with six-fingered hands," *Nature communications* 10, no. 1 (2019): p6, https://doi.org/10.1038/s41467-019-10306-w.
[709] Mehring et al., "Augmented manipulation ability in humans with six-fingered hands," p6.

This analysis of how we address minoritarians in research discourse shows a noticeable shift in how we perceive, describe, and refer to those with varying abilities. There is a tendency to use comparisons between body morphologies to discriminate against those who don't meet the thresholds of normative body configurations. Later, I shall propose how these shifts demonstrate that altering our attitudes and intersubjective language has qualitative effects on the intrasubjective lives of those we impact with our semiotics.

Subjectivity of augmentation

Prattichizzo et al.'s review (discussed in Chapter 3) raises several issues that are often ignored by other reviewers and scientists working in the SRF field. Prattichizzo et al. have been interested in furthering topics that are often considered outside the scope of SRF development and within the purview of other fields, such as neuroscience. Prattichizzo et al. consider research on the subjective experience of a user's mind in augmenting an SRF and incorporating ideas that include notions of the 'body schema' in the process of embodiment.[710] The problematisation and examination of mind-body schemas as a move towards embodiment thus becomes a reframing of individuals with minoritarian subjectivities from the standpoint of people with polydactyly. Therefore, it also affords the space to reframe the subjectivities of typical healthy individuals with five fingers in their desire for augmentation, including those with an SRF. It also helps further their intrasubjective perceptions of themselves in reconstructing their ideas of their subjectivities when it comes to altered body morphology and schema.

Prattichizzo et al. advance and further promote their proposition, enlisting broader ideas through philosophy. They cite Artistole's *De Partibus Animalium,* which suggests 'Anaxagoras says that humans are the most intelligent of the animals because of their hands.'[711] By invoking the hand's value as a civil and technological evolutionary instrument and an existential tool to build society, this philosophical argument valorises the hand and its contributions that make humans a unique social species. In the introduction to Chapter 3, the evolutionary nature of the hand is discussed, with reference to the contributions of the great anthropologist John Napier. This explanation helped position the hand and its significance to life as we know it. Prattichizzo et al. have also given attention to the evolutionary implications of this significant paradigm. They do this by extending the ramifications of a fully augmented SRF and considering the effect on 'sensorimotor bodily skills' - the

[710] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p15.
[711] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p18.

body's intelligence system and its neurocentric responsibilities for sensory and motor functions. The discussion of augmenting an SRF has a wider social impact when the augmentation of cognitive abilities involving BMIs[712] becomes commonplace and a part of the larger social equation. Such a mind meld poses an interesting question about the emergence of prospects for societies and human evolution. Prattichizzo et al. advise that, '[r]elegating the augmentation of bodily intelligence to a secondary role might unbalance cognitive and bodily skills development of our species.'[713] Suppose we consider this for a moment, and then we may ask why such an important question, posed by the SRF paradigm, has not appeared in the existential reflections of other researchers on the SRF. These deliberations have a material impact on how we develop the SRF. Prattichizzo et al. also think more broadly about another paradigm shift in SRF technology where 'motor augmentation can even occur *far* from the human body (e.g. with a grounded robot).'[714] This refers to being augmented with a robot that is controlled remotely. Prattichizzo et al. suggest augmenting robots with the ability to feel, sense, and supervise/control them in their environments through neural integration using sensory interactions. Although very rudimentary, this technology is now available in the form of sensory-motor interfaces integrated into SRFs through proprioceptive, sensorimotor interfaces, and exteroceptive sensors embedded within them.[715] Suppose we extend and extrapolate Prattichizzo et al.'s ideas even further. In that case, a radical shift in thought illustrates the potential for humans to receive motor-sensory feedback from their environments or to be totally immersed in the landscapes they inhabit, even sharing each other's feelings and thoughts. This paradigmatic shift also extends our sense of ourselves and our context, while being integrated with our surroundings, whether far away or near the body, and it responsively enmeshes those environments in ways that are unimaginable today. Expanding the body's workspace alters our ideas of perception, embodiment, body schema and peripersonal space, intersubjectively and intrasubjectively, as suggested in the most literal interpretation of Guattarian thought. This process involves embedding sensors in SRFs, robots, and all objects and subjects where sensors can be integrated, including those found in nature or other biological life. And the feedback would radically alter our views of how we see and sense the world. Essentially, it will ultimately impact how we perceive and understand subjectivity. Prattichizzo et al. suggest:

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[712] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p18.
[713] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p18-19.
[714] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p19.
[715] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p10-11.

> The consideration of non-wearable SRLs also opens the study of what are the neuroscientific implications in the perception of peripersonal space, body representation, sense of agency and, possibly, embodiment when using robotic devices which are physically detached from the user but connected to her/his body through a wearable sensorimotor interface. Current literature on these topics mostly considers wearable fingers.[716]

This significant leap extends subjectivity beyond peripersonal space, as mentioned. It extends the very limited notions of subjectivity, 'to be', 'to be human', or as they note, 'to be far from the human body' in connection to other environments. Surely, this change would transfigure our conceptions and pathways to understanding when we relate to otherness, other things, and other people. It provides a new realisation where the individual becomes a part of something yet unimagined, unlike anything we have so far considered when it comes to subjectivity and the configuration of the unconscious across the undulating surface of the planet. Guattari's revolutionary ideas on subjectivity embody these existential territories that can be realised through today's and tomorrow's technologies. Resting and embedded in the idea of transversality lie the very foundations that allow subjectivity to contain these multivariant types of connection, which may be very challenging in more traditional forms of subjectivity. The underlying connections between transversality and desire, as well as those that manifest in the unconscious, can accommodate subjectivity's curious, empathic, and creative nature when positioned beyond the limiting factors of social and political systems that structure what it means to think and be.

The review of Yang et al. addresses the research on the significant effect of environmental feedback on changes in body schema and embodiment. They suggest, '[i]n general, the embodiment is a sense that emerges when the artifact's properties are processed as if they were the properties of one's own biological body.'[717] Given what we understand from transversality, the terrains of representation have the potential for many different assemblages of the body and sense of embodiment, altering our mental relationship to ideas and new ways of thinking. Yang et al. also note that the feedback received from the fingers' effects on the human schema is greater than that from any other area, including the face and ears.[718] This makes the human hand and its augmentation a primary point of investigation for such innovations that alter subjectivity. Therefore, for the SRFs, the potential for an embodiment that encompasses the world around us is significant and warrants further research on the subjectivity of such an embodiment.

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[716] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p19.
[717] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p635.
[718] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p635.

Prattichizzo et al. acknowledge that the boundaries between SRF body augmentation technics and other technologies 'that target the *cognitive* augmentation of human capabilities'[719] are being blurred. They speak about the imminent future, where we are brought closer to 'improvement of the processes of acquiring/generating knowledge and understanding the world around us'[720]. Even though Prattichizzo et al. use the latter remark concerning cognitive augmentation only, I believe its broader implications mean that SRFs and AI (Artificial Intelligence) technology[721,722] will be so tightly integrated that these ideas will further expand the question of subjectivity and agency. I suggest that this is not only an experiment in human evolutionary transition, but also one that will significantly impact social, political, and economic discourse by altering the economy of subjectivity, which encompasses the economy of everything as Rolink and Guattari would suggest.[723] The ideas about the dynamics that alter our sense of ourselves in relation to the world we live in align with Guattari's ideas on how technology (through technics of augmentation that transform us) and machines might emancipate subjectivities.[724] These ideas will be further explored in the next chapter, while discussing Guattari's idea of the *machinic.* For now, I refer to remarks by Tong et al. on the emergence of 'human-machine hybrid interfaces'[725] or systems and the rise from the 'development of artificial intelligence'[726] systems, which will be prominent in the future. I imagine that what Prattichizzo et al. call the 'interplay between the bodily intelligence of the human and the artificial intelligence'[727] is relevant to developing a successful SRF. Through the effects on subjectivity of changes in perception, proprioception, and somatosensation, our senses will significantly alter our consciousness, enabling a deeper understanding of unconscious expression and facilitating transversality. It will determine how we interact with our surroundings, world views, and relationships with one another, which will significantly change once we feel and see how interconnected we are. Just as Guattari would let institutional psychotherapy leak into a new field of institutional analysis, it is possible that Prattichizzo et al. might be prompting consideration of a supernumerary future that includes living technologies which will extend human subjectivity.

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[719] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p1.
[720] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p1.
[721] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p942.
[722] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p19.
[723] Rolnik and Guattari the production of subjectivity is even more important than the 'production of petroleum and energy' in Guattari, *Molecular Revolution in Brazil*, 1, p36.
[724] Guattari, *Molecular Revolution in Brazil*, 1, p408.
[725] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p937.
[726] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p942.
[727] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p19.

Substitute or supplement/augmentation

From the outset of the review, it is evident that there is great confusion among the researchers on a fundamental issue. Except for Prattichizzo et al., the researchers of the three other field reviews and the numerous individual papers cited in Chapter 3 could not clearly distinguish the purpose of their research. Some could not clearly state whether they were developing a prosthetic that substitutes for a missing limb, finger, or hand function, or one that supplements a healthy hand (the diagram in Figure 37 clearly shows the differences).

Some researchers validate their motivation for their studies in an attempt to help those with a lost finger or hand function while citing its dual usability for augmenting healthy hands. This dual usability of a single design may be possible. Still, the design issues vary considerably at a more detailed level, given that substitution and supplementation/augmentation have different needs and targets, as seen in Figure 37. This confusing, alternating justification or raison d'être for their research seems stuck in a normative bind, characterised by a well-meaning but misguided lack of foresight. The careless and loose use of the idea, along with a lack of objectivity, is deceptive. After all, the term SRF indicates the function of a supernumerary dimension in the namesake. It does not use the words 'prosthesis' or 'orthosis,' which privileges the idea of substitution.

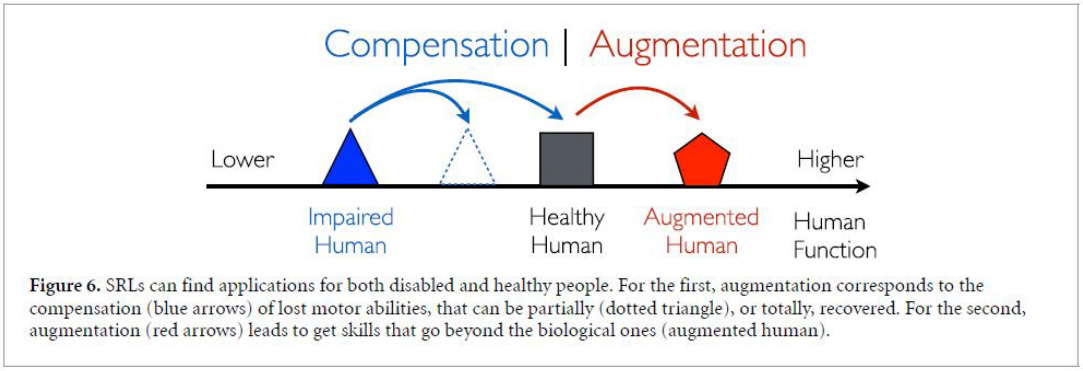

Figure 6. SRLs can find applications for both disabled and healthy people. For the first, augmentation corresponds to the compensation (blue arrows) of lost motor abilities, that can be partially (dotted triangle), or totally, recovered. For the second, augmentation (red arrows) leads to get skills that go beyond the biological ones (augmented human).

Figure 38- A diagram showing the differences between substitution (compensation) and augmentation (supplementation) taken from Prattichizzo et al.[728]

As one can imagine from the ideas presented by Prattichizzo et al. regarding the degrees of human function, there are other issues at stake here that are significant, such as the neuroscientific distinctions between a substitution where there has been neuromuscular damage, where the substituted finger has the advantage of cortical and neurological vestiges to accept that prosthesis, as opposed to a supplementation which requires new neural resource allocation capacities and brain

[728] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p16 Figure 6.

plasticity[729]. The issue of substitution versus supplementation is not directly correlated with how many extra fingers you get through the augmentation processes, whether four or eight fingers on one hand. It is a global or broader neuromechanical issue. It is a question of relying on neuromuscular and neurotechnology to service coordination and the commensurate load it places on the brain and its cortical regions.[730]

The point of contention between substitution and supplementation is not just a neurological one, but one that intersects with the agendas of diversity, accessibility, and privilege. For users who want to substitute for their hand or finger function, this represents a return to some semblance of access to ADLs (Activities of Daily Living). Even the concept of ADL is defined in very narrow terms by researchers, where the SRF is tested for a limited number of activities, such as whether a substituted finger using an SRF can allow the user to open a bottle single-handedly (see Figure 38).[731]

Figure 39 - Experimental validation shows a limited generosity to the user. Twisting off a bottle cap with the assistance of wearable robotic fingers was successfully tested on various types of bottles, taken from Wu et al.[732]

Surely, those who have lost finger and hand function wish to do more dexterous and varied tasks and activities. Researchers have not thoroughly considered these distinctions and issues, which significantly detract from the validity of their designs. The various designs of SRFs and their end effectors (fingers or tool attachments), as reviewed in Chapter 3, also require a closer examination of their anthropomorphic design (or lack thereof). For designs that are less anthropomorphic yet effective in ADL, we may need to readjust our understanding of what a hand equivalent can look like

[729] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p2,14-15.
[730] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p6-7.
[731] Wu and Asada, "Decoupled Motion Control of Wearable Robot for Rejecting Human Induced Disturbances."
[732] Wu and Asada, "Decoupled Motion Control of Wearable Robot for Rejecting Human Induced Disturbances," p4109 Figure 8.

and how it can function. It also requires foresight when designing products and buildings, as well as knowing how to accommodate these designs effectively. For example, switching a light off with a hook-end effector may be difficult. This challenge also highlights the levels of diversity and acceptance in our society regarding social discourse across all disciplines.

The point in question for other users with fully functioning hands is how accessible a third-thumb or any other SRF would be. How expensive will these technologies be, and where will they be available? What capabilities would they be able to have that would place them in a position of privilege? When getting employment, would a person with more fingers be favoured over one with fewer? And again, for those who choose to look different by supplementing their health hands, the issue of diversity and acceptance would need to be addressed in a world that currently has very normative ideas of the body and is intolerant of difference.

Another indication of the short-sightedness of most of the researchers reviewed is their lack of reflection on the broader issues fundamental to subjectivity and the user. Tong et al. have reflected this lack of foresight in their commentary. Their search identified over 2,194 papers, with their research cited in 272 individual papers.[733] Under the subheading 'VIII. Practical Applications' they fail to assess the potential impact and use of the SRF. They note, '[i]n this section, we will introduce its practical application in detail'[734], and they proceed to do that under five sub-sub-headings A-E, which include 'National Defence Military', 'Life Services', 'Medical Rehabilitation", 'Manufacturing and Industry', and 'Construction and Agriculture' - all utilitarian and capital driven activities aimed at production, consumption, and war. If we defer to Guattari's arborescent structures discussed earlier, it would point us to understanding that this type of thinking does little to incite or inspire novel uses, functions and expressions that the SRF might prompt in subjectivity. Tong et al.'s paper aligns with the other papers critiqued here for their evasiveness in the literature reviewed in Chapter 3, employing a similar approach in considering what an SRF does for society. These papers do not reference the impact on the user or the distinctions of the usage of SRF as either augmenting or supplementing users' capabilities. Nor do they speculate on the impact on social paradigms or wider negotiations. They bundle both types of usage, substitution, and supplementation together, and they reference mostly manufacturing and use as a prosthetic, as SRFs' main functions. Human function encompasses a wide range of diverse situational needs and considerations, which can be as nuanced as being singular, depending on factors such as subjective, aesthetic, health/medical, and technical needs, as well as the desire for pleasure.

[733] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p930.
[734] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p940-41.

When we think of SRF, we first must consider those with polydactyly and how we understand minoritarian issues concerning their desires. We must reconsider the subjective values of users in relation to social values or dictates and reflect on the discourse surrounding such matters. When researchers consider creating SRFs, they may need to consider the impact on subjectivity, not just the economic value an SRF provides to labour productivity. Whether we are helping shattered subjects (those who have lost hand function) regain control of their hand function or providing those who desire a techno-augmentative future to change their relation to their body and the world (an example will be discussed in a case study in Chapter 4E). These issues also must include equality and diversity. Learning from prosthetic users and those with polydactyly, as well as those using SRFs as a supplementation tool, provides a valuable basis for developing supplementation and augmentative SRFs. However, the design, use, and augmentive SRF capability needs are considerably different. Therefore, they might be well served if they are reflected in future research that considers individual human function.

Schizoanalysis, transference, transversality and the third-thumb

Reflecting on the theoretical and conceptual qualities of subjectivity through transference and schizoanalysis in the context of a third-thumb, is a useful way of understanding the hidden issues at stake in the field of SRF. Once again, I would like to clarify the difference between using the terms SRF and third-thumbs. SRF is the field in which a paradigmatic example is situated, which includes the research and researchers. As a theoretical reference, the paradigm of a third-thumb brings a subjective perspective to the discourse on SRFs, illustrated with a visual example of an additional thumb that highlights the importance of thumbs in their evolutionary impact. In this section, I aim to integrate the two disparate sections on theoretical, conceptual qualities, and technical particularities into a discussion that forms part of the methodology of this thesis. This method helps develop a multitude of connections to uncover ideas in a state of constant hidden anxiety.

Polydactyly and transference

The ideal model of the body is derived from institutions such as medicine and the media, as well as systems that model one type of body in their image. The projections by the medical community mirror the wider transference of social and political dimensions of the groups and institutions in the field of study in SRFs, revealing attitudes towards people with polydactyly. Transference can bring resistance to accepting such types of body diversity, creating isolated ghettos of subjectivity.

Transference carries numerous harms, as discussed in Guattari's critique of it.[735] The limiting values of transference can lead to alienation. In the descriptions given earlier, I contrasted my perspective on how Prattichizzo et al. and Bubshait MD characterise polydactyly - the former in the delight of diversity and its values, while the latter in an objective yet derisory affliction. My reflection aligns with Guattari's projections and transferential phenomena ideas discussed in this chapter, which I will now attempt to explain using a schizoanalytic modality, drawing on Guattari's thought.

Guattari has suggested that ideas of semiotics and significations territorialise our unconscious. These processes of signification through transference produce typified habitual outcomes centred on strict and structured ways of understanding subjectivity. The contrasts in language greatly unveil the difference in the semiotic systems, the 'regime of signs' and signifiers that reflect how attitudes are projected on behalf of the transferee. Through the transferential projection of Bubshait MD we see a very isolated and depersonalised (polarising, dehumanising) image of polydactyly as a disease and illness closely paralleling anxiety about others. Yes, it may be true that people with polydactyly may have other genetic morbidities coupled to those genetic markers, which Bubshait MD brings to our attention. If I were to suggest, Guattari would generously acknowledge the scientific nature of medicine, which requires some objectivity. However, these types of objectivity have politics that seep into the broader field of therapeutics, treatment systems, and the wider social sphere. The politics of the medical community are impacted by the semiotic stereotypes of the type, with their leftover (redundant) and overreaching meanings (what Guattari calls 'semiotic redundancies'[736]) that overflow to divide those with varied abilities from the rest of the population into a subclass in society in the name of therapeutic findings. The field of SRF is prone to discourses of correction, amendment, and enhancement of the body, rather than exploring extra-human possibilities. This is particularly evident in the context of polydactyly, where discussions often focus on correcting or enhancing the condition, rather than examining the positives, the satisfaction and pleasures of desires, and the formations of desires to come.

In these social processes of division brought about by semiotic redundancies, other forms of group and institutional biases replicate the approach found in this type of semiotics of language, as seen in medicine. Groups and institutions carry authority (i.e. subject-group: discussed in Chapter 2 and in detail in Chapter 4C). Because science is an institution of significant authority tied to funding regimes embedded in capitalism, there is a propensity to segment and use therapeutics to recover differences (push back to old habits) as an act of goodwill. However, Guattari suggests this may be

[735] Guattari, *Molecular revolution : psychiatry and politics*, p17-18.
[736] Guattari, *Molecular revolution : psychiatry and politics*, p76.

based on values towards labour in his ideas on or at the intersection of subjectivity and capital (IWC).[737] Therefore, recovery is part of a process of capital to bring back to the image of a normative human that is close to 'normal' and consistent with others (as it is reluctant to embrace diversity due to labour laws and normative habits). It will design systems for a five-fingered human on the production assembly line or its metaphoric equivalent until such time that the five fingers are no longer viable. Then, capital will be ready for the production process that will yield better profits with an extra edge. At that stage, everybody would migrate to the newer version of the hand, and those who don't would become minorities, dispossessed, and poorer in every way. We may encounter this link in phrases often used in the SRF discourse by notable reviewers, such as Yang et al., who frequently employ the broader umbrella of Supernumerary Robotic Limbs (SRL) when describing the need for SRLs in the workplace using terms like 'used in professional work'.[738] Others like Tong et al. use phrases like 'workers are often required to perform some complex and fatigue-prone task, such as assembling electrochemical systems, drilling holes', and so on.[739]

Suppose we have this view of the supernumerary-fingered individual, the individual who desires to augment an extra third-thumb. In that case, there must be a condition by which that individual should feel free to do so. If they cannot reconcile others with polydactyly, they will not be able to deflect their projections. Thus, the five-fingered individual is an isolated project with extinguished desires, trapped in the four walls that encircle the analyst and the analysand in transference. Therefore, all hope is lost for an altered subjectivity. In Guattarian terms—related to the latent desire of groups and institutions—this type of encirclement of perception or bias precludes us from the projects of transversality in which individuals can prosper and thrive. Being trapped in the alienation of minoritarian identity, with extinguished desire, has psychosocial repercussions on subjectivity. The traditions that carry the politics of punishment, blame, and shame imprison the subject, disallowing 'authentic existence'.[740] This burden on the subject requires their conformity and projections to function in the phallocentric, divisive, logocentric, colonial, and racialising modern societies that classify them in terms of class, gender, economic and social stratification, and so on. In its most extreme cases, we have seen this type of othering in the past, particularly in *microfascism*, which Guattari also references. This *microfascism*, as suggested by Guattari, is the fascism of the individual's infrasubjectivity and its inability to yield to desire.[741] Acknowledging the failures of transference and countertransference will avoid this type of *othering*. Those with polydactyly, for

[737] Guattari, *Molecular Revolution in Brazil*, 1, p53-54.
[738] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p623.
[739] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p941.
[740] Guattari, *Molecular Revolution in Brazil*, 1, p67.
[741] Guattari, *Molecular Revolution in Brazil*, 1, p86,90,185,317,54.

example, and countless other types of similar so-called disorders have relented to being mutilated due to so-called corrective surgery that tries to remove such appendages in an attempt to return the body to its normative image, which only serves the politics of dominant subjectivity, and I would also argue the politics of transference. In the spirit of transversality that overcomes these conflicts, researchers such as Mehring et al., who study the neural mechanics of polydactyly, warn us against such mutilations of polydactyly.

> These superior abilities of our polydactyly subjects, which may be specific to the preaxial group of polydactyly and to the well-developed SF in our subjects, suggest to thoroughly evaluate the functionality of an SF in polydactyly infants before deciding on whether to remove it.[742]

Until we dismantle such arborescent ideas that seek to classify people based on deviations from the so-called norm, there is no rhizomatic pathway to unleash the transversal connection between those with polydactyly and those without, creating free, flourishing individuals out of the black hole of shame and blame. Accepting polydactyly in society without discrimination is a therapeutic transformation that involves acknowledging our own transferential projections and resistances (transferential resistance, which was explained earlier) as we move towards the project of transversality. This action of transversality is the act of welcoming and accepting difference. Guattari reminds us that transversality allows us to understand the singular positions in which each individual is situated, an understanding without paranoia, without projection' (therefore transference).[743] The resistance to change perpetuates conformity, serving as a mechanism that allows discrimination and othering, in which class and social stratification prosper and are reinforced.[744]

The technocratic mindset of groups and institutions that produce studies on SRF displays the same level of indifference to the subject (the individual), as evident in the references to 'work' and 'industry'.[745] As discussed earlier, Guattari's schizoanalytic approach involves weaving together the smallest grains of insight that emerge through altered forms of perception, enabling the comprehension of other forms of subjectivity. Using this approach, we can start viewing researchers such as Prattichizzo et al., who have utilised their insight to gain a transversal understanding of polydactyly and their valorisation of difference, which is noteworthy in contrast to Bushait MD. I would argue that this insight by Prattichizzo et al. considers the subject and all its relations or systems of alliances, much like Guattari's propositions on transversality, as discussed so far. The alliances created by this bridge validate a view supporting the polyvalent scientific and social

[742] Mehring et al., "Augmented manipulation ability in humans with six-fingered hands," p6.
[743] Guattari, *Molecular Revolution in Brazil*, 1, p177.
[744] Guattari, *Molecular Revolution in Brazil*, 1, p52,338.
[745] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p941.

evolution of a techno-augmentation of a third-thumb, just as they valorise those with polydactylism. Guattari's schizoanalysis is a valuable tool for reconstructing the shattered subject and understanding interpersonal systems and infrapersonal relations within collectives and their environments. It provides space for the expansion of minoritarian subjectivity and supplements all subjectivities in their resistance to normative oppression from groups and institutions that perpetuate homogeneity. In this case, the polydactyly subject offers us a new hope in reconstructing differentiated desires and subjectivities. An additional note from Prattichizzo et al.'s proposition of 'motor augmentation [that] can even occur *far* from the human body (e.g. with a grounded robot)'[746] is another example of this differentiation of a subject that defies all normative concepts of peripersonal space, embodiment, and the boundaries of body schemas.

The discourse on polydactyly and supernumerary robotic fingers thus reveals how deeply our conception of the body is embedded in normative social and political structures. Through a Guattarian schizoanalytic lens, we have seen how transferential projections perpetuate the othering of bodily differences, creating isolated ghettos of subjectivity rather than celebrating diversity. The contrast between Prattichizzo's valorisation of difference and Bubshait's pathologising approach exemplifies how semiotic systems influence our perception of bodily variations. Only by dismantling these arborescent, hierarchical systems can we develop rhizomatic pathways toward transversality—accepting and embracing differences without projection or paranoia. The polydactyl subject thus becomes not merely an object of medical intervention but a potential catalyst for reconstructing differentiated subjectivity beyond the constraints of normative capitalism, opening new possibilities for understanding embodiment that transcends conventional boundaries of peripersonal space and body schemas.

Conclusion

In this chapter, I explored Guattari's concept of transversality and its operation in systems of subjectivity. I traced some related notions of transversality to explain how we confront the challenges and potentials of subjectivity through the augmentation of a third-thumb. I also gave an alternative perspective on some of the challenges I identified in the field of SRFs by contrasting the approaches of two groups of researchers. One researcher reflected on the customary medical classification of subjectivity, and another research group, whose radical reframing of alterity

[746] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p19.

contained the transversal and rhizomatic relation to the difference that Guattari speaks of. The outcomes of these are discussed below.

I first spoke about schizoanalysis and how it informs Guattari's social and political interfaces of subjectivity from a psychoanalytical perspective that breaks with traditional analytical concepts by examining and including the subjects' wider contextual environment. Guattari and Rolnik seek ways to liberate the individual from the constraints of psychoanalysis that perpetuate social and political conformity, bolstered by transference. Guattari's polemic on the transferential phenomena provided an opening to his idea of transversality, which considers subjectivity through rhizomatic and desirous facets of subjectivity. For Guattari, transference is a black hole that encircles the individual, leaving them stranded on an island, alienated without any consideration of their wider social and political problems. Hence, I examined how Guattari views transversality as a means of breaking free from the confines of psychoanalytic encirclement within transference. Drawing on an understanding of rhizomatic relations and alliances that work politically to challenge the core of arborescent structures, I observed how transversality relates to minoritarian groups that construct their subjectivities. I used the example of polydactyly as a priori to SRFs to demonstrate how Guattari sees the benefits arising from and extended to our understanding of our relationship with minorities, informing the lives of such struggles for all subjectivities, especially to forward the idea of an augmented third-thumb. I then provided a schizoanalytic perspective/exercise through the concept of augmenting a third-thumb using Guattarian transversality to shed light on the subjective potential for flourishing individuality, society and its evolutionary impacts. My commentary also addressed the critique of groups and institutions involved in the research on SRFs. This will be further elaborated in Chapter 4C, when I will refer back to Guattarian ideas on group therapy. Groups such as researchers were put under the spotlight in this chapter for their lack of insight into the wider impact of their research, which showed little foresight in understanding subjectivity within broader social and political contexts. I proposed ways of changing this type of conditioning through transversality.

The potential for human *techno-augmentative* capacity, such as a third-thumb, can expand techno-subjectivity by broadening our understanding of diversity, enhancing contextual comprehension of our environment, and valuing our relatedness. This relatedness arises when we employ transversal thinking in research, offering the potential to alter our perception. The desire to augment with a third-thumb may allow us to break free from normative, habitual, and arborescent thinking that divides us. Transversal thinking applied to what I term the techno-subjective augmentative altering can have a ripple effect in breaking down other arborescent social and political constructs contained in circumstantial and contextual realities that appear right before us—things like class, race, gender, colonial-racialising, logocentric, and phallocentric structures. Guattari's transversal thinking is an

ethical unconscious impulse that, once allowed to flourish, can transform our bodies, relationships with one another, and our interactions with the planet.

Chapter 4B - The machinic unconscious of SRFs

In the same vein as the previous chapter, the following chapter examines the theoretical and conceptual aspects of Rolnik's and Guattari's ideas on subjectivity, as well as the technological particularities of SRFs (and by extension the technics of the third-thumb). Herein, I extend the subthematics of subjectivity and extend the discourse on the qualities of transversality to include the ideas of the *machinic unconscious* and its various modalities. This includes understanding how the idea of the *machinic* works in *semiotics* and how it allows for rupture to travel in new directions from the habitual. After such an exploration, I delve into the SRF as a *mechanical* and/or *machinic* artefact and explicate some ideas before bringing the concept of the *machinic* and the SRF together to conduct a comparative analysis for the application of the theory to the field of SRF and the paradigm of a third-thumb.

Machinic unconscious and transversality

Machinic unconscious and assemblages

Guattari and Rolnik's conception of subjectivity inculcates a concept of *machines*. As previously discussed in Chapter 2, machines interact with other machines, creating creative pathways for the flow or connection of desires. These connections lead to assemblages of varied and heterogeneous ontologies. Such machines constitute flows of information, energy, ideas, messages, libidinal, or environmental flows, etc. A machine can be anything. A machine, in Guattari's sense, refers to a dynamic system that brings together various components, which can be social, technological, biological, or conceptual.[747] These components interact with each other to produce effects, flows, and transformations. The key characteristic is that machines are productive - they do things, create things, and transform things. Imagine a tree that is firmly planted in the ground. The machine that connects the earth to the sky through the tree is a machine that supplies the nutrients from the ground, allowing the tree to photosynthesise the sun's rays to produce sugars that nourish it and enable it to grow. In this way, machines are active multidimensional systems that make new and varied connections based on the harmonics of connections as determined by the resonances in the environment. Those resonances and harmonics come together when the sun, the air, and the right amount of water all operate at their optimum states and on the same working plane as one another.

[747] Guattari, *Molecular Revolution in Brazil*, 1, p43.

That may be the right temperature or pressure to enter the machine of the tree-sun-earth, allowing its biology to function.

Guattari's machinic systems operate actively to crisscross the environmental conditions as they operate transversally to (co)generate subjectivity. Like most of Guattari's concepts, the definition of machinic systems proves elusive and requires a more abstract thinking about the concept. In the book *Molecular Revolution in Brazil,* machinic systems are presented as unconscious systems of connection that respond to and connect desire with affect.[748] Hence, machines or machinic systems create new ground for connection and expression. Therefore, in Guattari's elaboration on the *machinic unconscious,* Guattari identifies a mechanism responsible for transforming unique, singular, and autonomous subjects, unleashing them in the unconscious through desire. To make things a little more complex, Guattari suggests that this machinic unconscious results from the production of machinic systems that interlink to create flows within and through the unconscious.[749] These flows encompass the convergence of unconscious thoughts, encompassing not only desires but also perceptions and resonances of connections that form and construct the Guattarian concept of the subject itself. This production is processual and created from connections between subjects and other influences/connections with one's environment or the environments of others, and their experiences. Guattari argues it in this way:

> In other words, the *machinic unconscious corresponds to the assemblage of the productions of desire and, at the same time, to a way of mapping them*. The machinic unconscious is what seeks to produce subjective singularities. This means that the formations of *the unconscious do not derive from a* déjà-là *but are constructed, produced, and invented in processes of singularization.*[750]

Though we can read this quote in multiple ways, I think Guattari is suggesting that by analysing the flows that produce the unconscious, we can map and trace the forces that animate it – a key force being desire. Guattari suggests that the production of subjects, or the subjectivation of the unique and singular individual, is achieved through processes that involve machines, which give rise to what he ultimately calls the *assemblages of enunciation* (introduced in Chapter 2).[751] This idea is a culmination of processes of transversality; it is sufficient here to note that Guattari states,

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[748] Guattari, *Molecular Revolution in Brazil*, 1, p310,53.

[749] Guattari, *Molecular Revolution in Brazil*, 1, p303. In an further example of Jean-Baptiste, Guattari demonstrates how social and political interlinking outside signifiers of transference and interpretation allows his understanding of the flows in the patients unconscious in Guattari, *Molecular Revolution in Brazil*, 1, p360-62.

[750] Guattari, *Molecular Revolution in Brazil*, 1, p310.

[751] Guattari, *Molecular Revolution in Brazil*, 1, p43.

'[s]ubjectivity is produced by assemblages of enunciation'[752]. *Assemblages of enunciation* can be considered a collection of expressions made up of collages of expression that convey a true mode of self-determination as described in the machinic, but this time they are expressed outwardly in utterances and multimodal ways of expression. This assemblage is representative of the producing forces of subjectivity, which, for Guattari, involves 'machines of expression'[753] that comprise all other types of machine. Some examples gathered in these assemblages would be the extrinsic machinic expressions of, for example, economic, social, and technological impacts on the subject, as well as the 'infrahuman, intrapsychic, and infrapersonal nature' of the subject, encompassing all modes of sense and sensibility.[754] Suppose we return to our example of the tree. Its mapping of its unconscious would be mapping its flows that provision its life-giving forces, that is, the flow of sugars and sap that nourishes it. The assemblages that comprise it are the assembly of machinic systems that interconnect and produce its flows and systems. The biological, molecular, and microbiological processes (machinic processes) they encompass help it produce and yield the sugars and sap it subsequently metabolises, which sustain it. This included the environment that takes shelter under its canopy, as well as the plants and microbes that assist it in gaining water and nutrients from the soil.

Guattari's concept of the machinic unconscious thus offers a profound reimagining of how subjectivity emerges. Far from being predetermined, it actively produces singularity through dynamic assemblages of desire, connecting heterogeneous elements across biological, technological and social domains. These productive systems—such as a tree's metabolic relationship with the earth and sky—create flows that shape both expression and consciousness. Through these interconnected machines, subjectivity is not merely revealed but continually constructed, allowing for new pathways of becoming that transcend traditional boundaries of selfhood. The machinic unconscious represents not just a theoretical model but a revolutionary approach to understanding how we are constituted through processes of transversal connection.

Machinic and the mechanical

Guattari distinguishes the subtleties between the terms '*machinic*' and '*mechanical*' systems. He says that, unlike mechanical systems, his machinic systems are based on highly differentiated desires that

[752] Guattari, *Molecular Revolution in Brazil*, 1, p43.
[753] Guattari, *Molecular Revolution in Brazil*, 1, p43.
[754] Guattari, *Molecular Revolution in Brazil*, 1, p43.

drive them to alter subjectivity. Similarly, he says semiotic machines work to influence our ideas about ourselves:

> *I think it is much more useful to aim for a theory of desire that considers it as belonging rightfully to highly differentiated and elaborated machinic systems*. When I say "machinic," I am not referring to the mechanical, or even necessarily to technological machines. Technological machines exist, of course, but there are also social machines, aesthetic machines, theoretical machines, and so on. In other words, there are territorialized machines (in metal, electricity, etc.), just as there are also deterritorialized machines that operate on a completely different level of semiotization.[755]

Although Guattari attempts to bridge our understanding of what constitutes a real machine (technological machines) with his more abstract ideas of machines, his explanation is hindered by the inclusion of too many ideas and references to complex concepts, making it difficult to follow. The relevant point here is that Guattari suggests his machinic concept spans the territory of non-manifest machines to theoretical realms. His machines are at once symbolic and metaphoric, and actual or 'concrete machines'[756] of a more technological character. By way of an alternative, Guattari conceptualises the machinic as a philosophical system that might play itself out as 'social machines, aesthetic machines' and 'theoretical machines'.[757] This is done so he can explain how they connect with the subjectivity of the unconscious and the milieus of the collective. Machines draw us closer to the systems of interaction, interconnection and assembly through affect and cognitive recognition that responds to our desires. An example would be an art machine that sweeps us up as a group or audience when we are so affected by our experience of it. Here, we have a collective machinic unconscious in operation. Collectively, it brings together the various machines of affect in unison to construct an emotional, creative force that stirs subjectivity into an alternate state.

I would like to draw your attention to the appendix in *Molecular Revolution in Brazil*, specifically the heading 'Notes About Certain Concepts to *Molecular Revolution in Brazil'*, which highlights the discourse that distinguishes the importance of the term 'machinic' when contrasted with the term '*mechanic*'. Rolnik defines the difference between machinic and mechanical (mechanic) in this way:

> Machine (machinic): Here we distinguish between the machine and mechanics. Mechanics is relatively self-enclosed; it only maintains perfectly coded relations with exterior flows. Machines, on the other hand, considered in terms of their historical evolution, constitute a phylum comparable to those of living species. They generate each other, select each other, or eliminate each other, bringing out new lines of potentialities. Machines in the broad sense (i.e., not only technical machines, but also

[755] Guattari, *Molecular Revolution in Brazil*, 1, p353.
[756] Guattari, *Molecular Revolution in Brazil*, 1, p401.
[757] Guattari, *Molecular Revolution in Brazil*, 1, p353.

> theoretical machines, social machines, aesthetic machines, etc.) never operate in isolation, but by aggregation or assemblage. A technical machine in a factory, for example, interacts with a social machine, a training machine, a research machine, a marketing machine, etc.[758]

In this passage, Rolnik distinguishes between 'machine and mechanics' and, simultaneously, critiques mechanics, building on the machinic concept presented so far by Guattari. In Guattari's machinic explanations, he reflected on the inherent capacity of machines to connect readily with other machines. And to do so engenders a form of 'aggregation' which Guattari and Rolnik call 'assemblages'. Rolink's reference to 'historical revolutions' implies that the varying propensity for this complex level of connectivity, in which we view history critically, allows it to be read or interpreted in various versions depending on how we scrutinise and present it. Histories can be recited in multivariant ways if critically examined. Most histories are told by those in power or those who dominate. Guattari generally knows this *cut* of history or each unique interpretation or version of history as a *phylum*. As such, there are many phyla to consider when examining the same historical event, depending on how we approach its critical appraisal.

In comparison, subjectivity represents a complex assemblage that needs to be viewed from different angles according to Guattari and Rolnik.[759] Each angle, cut or each phylum shows a different propensity for 'potentialities'. Mechanics, on the other hand, is unequipped for such dynamic multivariant proficiency. It remains as one single reading, phylum or cut. In mechanical systems, the relations and the cuts, otherwise called 'coded relations', don't alter, always reflecting the same cut or phylum. There are no possibilities other than the set hard 'coded relations', or frozen chronicles of connections, no contingencies and equally no capabilities for the emergence of new connections other than its singular set of flows.[760] In isolation, when Rolnik and Guattari speak of subjectivities that are mechanical, they refer to subjects that exhibit a limited capacity to connect with their environment, often allowing their superego to be defined in a singular relation to the other. Their reference to the ways of being is often informed by social systems that convey modelling of subjectivities via the process of semiotization or semiotics, that is, ego ideals through language and a system of signs. Moreover, it is essential to note that, for Guattari, machinic systems utilise transversal connections through their multifaceted relations, which combine desire into systems of flows, cuts, phyla, and cutting flows, thereby engendering new streams of flow that make them interconnected systems of relations.[761] These new connections unleash the flows of potentialities for

[758] Guattari, *Molecular Revolution in Brazil*, 1, p466-67.
[759] Guattari, *Molecular Revolution in Brazil*, 1, p466-67.
[760] Guattari, *Molecular Revolution in Brazil*, 1, p466-67.
[761] Guattari, *Molecular Revolution in Brazil*, 1, p465.

extraordinary possibilities. They have an oneiric quality. The machinic systems, like that of the unconscious, thus happen through their 'aggregation or assemblages' intersecting many other existential (theoretical machines) and concrete territories (such as robotics)[762] , creating so many existential possibilities. Each one is unique to one particular subjectivity or particular to the transindividual and the contexts of their situations. Christoph Hubatschske succinctly suggests '[i]t is all about combinations and arrangements, conscious and planned ones, but also more particularly unconscious, unplanned, and maybe even unrecognized ones. A technology therefore is not something already defined but something always already situated.'[763] However, as we shall see in the coming sections, the distinctions between machinic and mechanical are very much in operation when we think about how a mechanical edifice like the SRF has many ontologically machinic possibilities in its technological-biological assemblage (augmentation of the hand with a third-thumb). The conjunction produces numerous substantive social, cultural, economic, and subjective possibilities that can alter and be part of a total wave of material and theoretical revolutions.

Semiotic machines– free machines in transversality

To make matters more complex, I will revisit the issue of semiotisation, or semiotics, when discussing Guattarian machinic subjectivities, extending the idea further (as mentioned above). Semiotics is more than an understanding of language (or the systems of signs – semiosis); it is, broadly, an understanding of the systems of signs, in which language is its subset. We need to understand how Guattari sees the differentiation between semiosis and semiotics.[764] Although many people use 'semiosis' and 'semiotics' interchangeably today, they have distinct meanings. Semiosis is the process of meaning-making through signs, focusing on the actual, dynamic way in which signs are interpreted and produce meaning in practice. Semiotics is the theory or discipline that studies how signs work, functioning as a broad intellectual framework. For example semiosis refers to the moment when a driver sees the red light and understands its meaning as 'stop,' interpreting it in real-time within the context of driving - while in in semiotics, you might analyse how a red traffic light functions as a sign within a system of road signals (the light represents 'stop'). Guattari puts it in the following ways:

[762] Guattari, *Molecular Revolution in Brazil*, 1, p466.
[763] Christoph Hubatschke, "How to Dance with Robots," in *Machinic Assemblages of Desire*, ed. Paulo de Assis and Paolo Giudici, Deleuze and Artistic Research 3 (Leuven University Press, 2021), p214.
[764] Félix Guattari, *The machinic unconscious : essays in schizoanalysis*, Semiotext(e) foreign agents series, (Los Angeles, CA: Semiotexte, 2011), p22.

-*semiology* as a trans-linguistic discipline that examines sign systems in connection with the laws of language (Roland Barthes' perspective); and

-*semiotic*s as a discipline that proposes to study sign systems according to a method which does not depend on linguistics (Charles Sanders Peirce's perspective).[765]

Guattari is a semiotician, and although he employs semiosis, his concern centres on the processes by which meaning is produced, transmitted, and interpreted. Guattari investigates how signs function in communication and culture, analysing the relationships between signs, signifiers, and signifieds. Guattari uses semiotics and explains its machinic dimensions (connective assemblage). When he refers to 'machines that operate on a completely different level of semiotization'[766] he is referring to the ability of the various machinic systems that can manipulate language to distort its meaning to suit their own needs through their machinic connections, reorienting the relationships between signs, signifiers, and signifieds. To explain this, I mentioned earlier that subjectivities are prone to being imprinted through semiotic inferences (through the superego).

And though Guattari's understanding is highly elaborate and sometimes incomprehensible, for the moment, it suffices for us to understand that Guattari's coupling of semiotics and subjectivities has many valencies. In essence, one can construct the other and vice versa. Semiotics influences the production of subjectivity, and subjectivity also dispenses semiotics. As mentioned earlier in this chapter, Guattari's view on this is that '[s]ubjectivity is produced by assemblages of enunciation'[767]. We can appreciate from this idea that machines can disseminate, digest, metabolise, and mediate semiotics. By meditating, I mean they can interject to change and alter the meaning. When discussing transversality within subjectivity in its social context within assemblages of enunciation, one facet of the mediation of semiotics is how our notion of the world is shaped by certain retellings of history, particularly those that are racialising-colonial, phallocentric, logocentric, and dominant systems, or the media systems that support them.

What is provided by this mediation process is usually readily interjected and consumed by subjectivity. However, in subjectivity, the mediation of signs, signification, and the system of pragmatics that forms what is shared and understood habitually arbitrates the relations of the subject with itself and others. Guattari explicitly suggests that mediation in subjectivity is 'by means of the media and collective facilities'[768] and arbitrates ideas and their meaning in the process of comprehending messages to the superego and psyche, often seemingly by osmosis. The mediation

[765] Guattari, *The machinic unconscious : essays in schizoanalysis*, p22.
[766] Guattari, *Molecular Revolution in Brazil*, 1, p353.
[767] Guattari, *Molecular Revolution in Brazil*, 1, p43.
[768] Guattari, *Molecular Revolution in Brazil*, 1, p469.

of semiotics also implies that desiring machines can be trapped in reverse engineering to execute meanings that are otherwise the expressions of collectives, institutions, and organisations. Machinic processes mediate the interpretation of signification and the comprehension of semiotics, providing imports that shape the subject, which are contingent upon the substrates of socio-political systems of production, as found in groups and institutions. Semiotics are always structured or stratified through their interaction with the environmental context. Why is this important? It is important to Guattari because semiotics and significations place subjectivity at the intersection of contextual politics and economies of social arbitrage with its osmotic import, constructing subjectivities in assemblages of enunciation. Guattari proposes that 'machinic subjective production, which has to do with modes of expression that involve both language and the most varied semiotics.'[769] Thus, understanding the machinic systems of semiotics, for example, greatly impacts the 'inputs of vectors […] that are intrinsically bound up with the processes of analysis.'[770] Therefore, by employing analytical processes that trace the effects of semiotics on assemblages of enunciation through inferences that can be traced back to their source via reverse analysis, it is possible to unravel the origins of inputs that give rise to subjectivity. As discussed in the previous chapter, the therapeutic act of deciphering the wider analysis of semiotic meanings is also a fundamental act of schizoanalysis, which is deeply intertwined with enabling the processes of transversality in free and open societies.

We have already established that the processes of transversality that can free subjectivity in creative ways from semiotic enslavement are achieved through the 'machinic nature'[771] that permits 'lines of flight'[772] away from subjective entrapment. So, the machinic nature can both entrap and be free - after all, machines of desire are not oriented in a single specific direction. They are machines of connection, not machines of orientation or bias. I will return to this in the section where I shall analyse SRF through Guattarian ideas. For now, I think that, for Guattari, machines express a system characterised by making connections, allowing flows and cuts, and 'systems of cutting flows'[773] that configure these *ruptures*. This is to say, in the simplest terms possible, the machinic is the bringing together of elements to produce (a flow) that might also cut or break (a flow) that suddenly ruptures away from normativity. I shall return to the use of the term *ruptures*, but for now, ruptures will represent an escape from a habitual way of being. A window, for example, might be seen as a machine that segments a view of a framing of the sky into a rupture that is a digestible segment. The

[769] Guattari, *Molecular Revolution in Brazil*, 1, p339.
[770] Guattari, *Molecular Revolution in Brazil*, 1, p33.
[771] Guattari, *Molecular Revolution in Brazil*, 1, p35.
[772] Guattari, *Molecular Revolution in Brazil*, 1, p438.
[773] Guattari, *Molecular Revolution in Brazil*, 1, p465.

entire sky, snow, and thunder are in a type of flow that might be too much for an individual and lead to hypothermia if not accompanied by a window.[774]

In contrast, the window machine is a system that breaks up or cuts the flow, framing a small segment of the entire sky. This machine-like contraption frames the flow of the sky so comprehensibly that an individual still has access to and a connection with (air, view, and light), but is not swept away by the flow. Through the window, it is possible to witness the ever-changing landscape and thus be part of the ever-changing potential of the outside whilst being protected by the inside.[775] By using blinds and curtains, you can instantly transform the window's character, controlling the light and aperture of the view. Suddenly, the relationship between the interior and the outside fluctuates. It becomes darker and moodier. This is the machinic rupture of the window's nature, altering the window's relationship with the viewer. I also think that speaking about things in terms of their machinic nature for Guattari is a way to depersonalise and de-anthropomorphise the connectivity between subjects, objects and contexts, giving ground to an equal, balanced way of understanding how things can seemly connect without judgment or bias, simply based on the nature of the drives that Guattari calls desire.[776] Making the flow between machines so fluid that it travels through the sky, the snow, the thunder, the sun, and the window frame allows the window and the person behind it to be part of one machine —the person-viewing-sky machine. It is a way for Guattari to describe systems that function and connect across and beyond human to non-human, 'incorporeal entities'[777], extending subjectivity into its environment (all environments, social, political, economic, cultural and so on). The flow thus becomes the focus, rather than the elements that connect, making them indescribable, except by referring to them as machines. It allows these machinic systems to connect and exist without being limited to boundaries set by psychoanalytic and anthropomorphic thinking systems. The individual standing at the window, enjoying the view, is themselves part of the window-viewing-sky-machine that has moved into the realms of transversality, where affect sweeps them up in beauty and wonderment. However, the individual is no more special from a machinic perspective than the glazing, the frame, and the wall in which the window is situated. They work on the same level of interaction (on the same plane of immanence discussed in Chapter 2) and speciality, which are all equally important as the sum of their parts and

[774] The idea of the window is taken from Smith, *Tranvsersailty Lecture 10*. It is also based on his writing on his chapter on Transversality titled 'Transversality' in Chris L. Smith, *Architecture after Deleuze and Guattari*, 1st ed. ed., Deleuze and Guattari Encounters, (London: Bloomsbury Academic, 2023).
[775] Smith, *Tranvsersailty Lecture 10*.
[776] Guattari, *Molecular Revolution in Brazil*, 1, p393.
[777] Guattari, *Molecular Revolution in Brazil*, 1, p465.

all necessary for the assemblage to produce. They become part of the production of the assemblages of enunciation, the pronunciation of wonderment, that articulates affect as beauty.

These explanations are especially relevant to understanding the Guattarian unconscious, the psyche, and its relations to differentiated and elaborated[778] notions of desire. By referring to machinic systems, Guattari sweeps up all systems from various assemblages into systems with a 'processual nature'[779] into a framework of connections and flows. There are many possible ways to speculate how he arrived at this theory, from the concept that he devised with Gilles Deleuze called 'bodies without organs'[780] to his reference to deep empathy with what 'Marx called the infrastructure of production'[781] in which he always speaks of 'machinic production'[782]. I won't explore this derivation further, except to make the point that for Guattari, 'subjectivity is produced'[783] just like an assembly line.[784] The subjectivity of someone without windows radically differs from that of those with a view. And this is very important.

There are countless examples of various types of Guattarian machines. Guattari transposes the de-anthropomorphisation of many systems into his notion of the machinic, such as 'semiotic machines'[785], 'machines of expression'[786], 'abstract machines'[787], 'theoretical and literary machines, machines of sensibility'[788], 'machines of State control'[789], 'machines for struggle'[790], 'automatic machines'[791], 'great machines of production and social control'[792], 'mutant machines'[793], 'machines

[778] Guattari, *Molecular Revolution in Brazil*, 1, p353.
[779] Guattari, *Molecular Revolution in Brazil*, 1, p335.
[780] Guattari, *Molecular Revolution in Brazil*, 1, p415.
[781] Guattari, *Molecular Revolution in Brazil*, 1, p39.
[782] Guattari, *Molecular Revolution in Brazil*, 1, p32.
[783] Guattari, *Molecular Revolution in Brazil*, 1, p43.
[784] Rolnik and Guattari elucidate the concept of subjectivities produced like industrial products on an assembly line in the section called The Assembly Line of Subjectivity in Guattari, *Molecular Revolution in Brazil*, 1, p53-94.
[785] Guattari, *Molecular Revolution in Brazil*, 1, p251.
[786] Guattari, *Molecular Revolution in Brazil*, 1, p43.
[787] Guattari, *Molecular Revolution in Brazil*, 1, p466.
[788] Guattari, *Molecular Revolution in Brazil*, 1, p64.
[789] Guattari, *Molecular Revolution in Brazil*, 1, p68.
[790] Guattari, *Molecular Revolution in Brazil*, 1, p74.
[791] Guattari, *Molecular Revolution in Brazil*, 1, p79.
[792] Guattari, *Molecular Revolution in Brazil*, 1, p91.
[793] Guattari, *Molecular Revolution in Brazil*, 1, p256.

of subjectivation'[794], 'technological machines'[795], 'aesthetic machines'[796], 'concrete machine'[797] , 'war machines'[798] and many more including 'narcissic[sic] machine'[799] and 'bachelor machines'[800].

Guattari would rather not have to refer to ideas in terms of good or bad when it comes to machines, as I have already touched on with their orientation and biases. He likes to avoid 'Manichean dichotomy'[801] (discussed in Chapter 2) when speaking about the machinic because he doesn't believe they are subject to good or evil but rather to distinguish the intrinsic analytic character of machinic systems. It's the analytical meaning and the processual nature that allow for comprehension. There are no value judgments regarding the window-sky-person machines.

I have spoken about how machines can have transformative effects, with their positive, life-affirming outcomes benefiting subjectivity. On the other hand, Guattari gives us examples of machines that can operate and have detrimental effects on subjectivity in the 'production machine of capitalistic subjectivity'.[802] According to Guattari, abstract machinic systems can fall under the spell of capital and become 'great machines of production, the great machines of social control, and the psychic agencies that define the way of perceiving the world'[803]. These machines lack transversality. Like the 'semiotics machines'[804] of capital, which are slaves to the production machines and 'media'[805] machines, they can alter subjectivities, binding them tightly to the rules of labour and containing the body to a very strict subset of ideas on subjectivity[806] through their influence on the superego[807]. Guattari proposes 'a certain kind of functioning of the domestic economy, the social economy'[808] that is here enslaved to 'dominant subjectivity'[809]. In our example of the window, it is like having a view of nature, but instead, there is a photo of the landscape with one constantly, never-changing reference to the sky and the landscape—a window machine lacking the flows of the sky, thunder and wind.

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[794] Guattari, *Molecular Revolution in Brazil*, 1, p299.
[795] Guattari, *Molecular Revolution in Brazil*, 1, p353.
[796] Guattari, *Molecular Revolution in Brazil*, 1, p353.
[797] Guattari, *Molecular Revolution in Brazil*, 1, p401.
[798] Guattari, *Molecular Revolution in Brazil*, 1, p251.
[799] Guattari, *Molecular Revolution in Brazil*, 1, p424.
[800] Guattari, *Molecular Revolution in Brazil*, 1, p422-26,93.
[801] Guattari, *Molecular Revolution in Brazil*, 1, p403.
[802] Guattari, *Molecular Revolution in Brazil*, 1, p55.
[803] Guattari, *Molecular Revolution in Brazil*, 1, p37.
[804] Guattari, *Molecular Revolution in Brazil*, 1, p251.
[805] Guattari, *Molecular Revolution in Brazil*, 1, p57.
[806] Guattari, *Molecular Revolution in Brazil*, 1, p409.
[807] Guattari, *Molecular Revolution in Brazil*, 1, p54-56.
[808] Guattari, *Molecular Revolution in Brazil*, 1, p409.
[809] Guattari, *Molecular Revolution in Brazil*, 1, p410.

Guattari elaborates on how some machinic processes can capture the subject and subjectivity. Here, Guattari refers to the use of machines by elites and those in power to control society:

> Machines are acquiring increasing importance in production processes. Relations of intelligence, control, and social organization are increasingly closer to machinic processes; through this production of capitalistic subjectivity, the classes and castes that possess power in industrial societies seek to ensure increasingly despotic control over production systems and social life.[810]

So, the machinic process can capture subjectivity according to Guattari. I suggest that the discourse on the SRF has aspects that make it particularly susceptible to the lure of producing capitalistic subjectivity. This is possible if only elites have access to the SRFs, making it a tool of privilege. In augmentation, when the psychology and subjectivity of the individual are entangled with the SRF, if the SRF is used in nefarious circumstances of capture, like the extraction of work and to increase productivity, Guattari suggest this can lead to 'industrial societies […] increasingly despotic control over production systems and social life' when compared to his elucidations above when talking about rutpures and lines of flight to free autonomous subjectivity. It is possible to describe the SRF as subservient to capitalist production when it considers the SRF as a 'successful project' and when it allows a person to maximise their capacities for work purposes (increased labour). In this case, it is also possible that the positive liberation of a subject through transversality might simultaneously involve their insertion into the great capitalist machine. Machinic production of subjectivity can be viewed from both perspectives. Machinic processes can also turn the other way and become liberating systems that deploy progressions allowing the unconscious to make transversal connections corresponding to singular or unique subjectivities. An unconscious free from the competing interventions of commercial media and political propaganda machines can express its desires more freely. If an SRF allows someone to access a pleasure point that they could not reach without it, then you can imagine that the SRF is less a machine of subjugation and more a machine of pleasure, a machine that satisfies the unconscious need for expression. A type of 'desiring machine'[811] as Guattari might call it. At a more social than individual level, Guattari gives an example of the machinic possibilities of technologies via his experience with free radio.

> Free radio stations, challenging the system of political representation, questioning daily life, and reactions that refuse work in its current form, are viruses contaminating the social body in its relation with consumption, production, leisure, communications media, culture, and so on.[812]

[810] Guattari, *Molecular Revolution in Brazil*, 1, p54.
[811] Guattari, *Molecular Revolution in Brazil*, 1, p465.
[812] Guattari, *Molecular Revolution in Brazil*, 1, p63.

Guattari may have been ahead of his time. Considerable discourse about today's social media machines teaches us how they greatly influence subjectivity. Guattari says, 'modern capitalism produces a new kind of subjectivity on a large scale by means of the media and collective facilities'.[813] Thus, the semiotic machines impact subjectivity and can liberate and alter perceptions. When examining the SRF, I shall look at the semiotics used in the discourse in terms of the machine of the SRF.

Machinic ruptures

Finding a way to break through the processes of capitalistic subjectivation or subjectivation via other dominating and totalising processes requires a radical departure. The machinic systems that work to create free and autonomous subjects can be considered the function of a developing field of transversality through their 'machinic ruptures'.[814] Ruptures can extricate machines from structured control systems and provide alternative pathways for connecting ideas and people. Similarly, mutant machinic ruptures seem to be mediated by affect and escape the dominant modes of control,[815] making them so intrinsic to transversality. Their breaks in flow tend to lead to a greater sense of openness concerning social systems and widen the interpretation of semiotic systems, making them more inclusive and broader. Machinic ruptures that broaden semiotics and work towards schizoanalysis can also divest from the dominant discursiveness of language, offering new meanings and opening up new possibilities in further types of interpretation. For Guattari, 'mutant aspects of what I call "machinic processes" (theoretical and literary machines, machines of sensibility, etc., and not just technical tools found in production)'[816] are part of this definition. Machinic ruptures are, more importantly, spoken of as 'heterogeneous machinic systems'.[817] The use of the word 'heterogeneous' is important. It makes it clear that the machinic ruptures are not about totalisation, nor the homogenisation of the elements that are brought together. As in the example used, every element of the window-view-sky machine can be equally deployed in another machine. The person looking out into the night sky may turn away from the window and become part of the book-lamp-reading-literature machine. A blind might be drawn across the window to transform the glass from the art of a view machine into a part of the insulation-heat machine.[818] The mutant-heterogeneous machinic systems that Guattari describes tend to be diverse because they cross-regulate boundaries

[813] Guattari, *Molecular Revolution in Brazil*, 1, p469.
[814] Guattari, *Molecular Revolution in Brazil*, 1, p254.
[815] Guattari, *Molecular Revolution in Brazil*, 1, p256.
[816] Guattari, *Molecular Revolution in Brazil*, 1, p64.
[817] Guattari, *Molecular Revolution in Brazil*, 1, p362.
[818] Smith, *Tranvsersailty Lecture 10*.

and strata, allowing for a complex interplay of elements. They are rhizomatic in character as discussed in Chapter 2.

Guattari is greatly interested in 'information machines'[819], 'the revolution of computers, telecommunications, robotics, and so on'[820] and 'mobilizing cybernetic resources and the most sophisticated technology'[821]. He sees the technics of machines as abstract machines that cut across the flows of dominant subjectivity to produce singular individual assemblages of enunciation. That is, assemblages of expression that bring into concrete terms a fresh horizon of seeing, viewing, and thinking about things. Although he warns us about the technologies' ability to control subjectivities and ways of living, he also appeals to us to use them for their revolutionary potential. He suggests that with some help, these technologies can become 'great machines for struggle'[822] for our bodies' sovereignty and subjectivities. He suggests, '[t]hese components constitute a kind of raw material for the very texture of our societies. These components cannot be understood at all based on theories like that of the signifier, as elaborated and placed in circulation in the Lacanian and post-Lacanian situation.'[823] Guattari points out that only the therapeutics of transversality can elevate subjectivity into active, thriving positions found within the potentialities of these technologies. Transversality overhauls outdated modes of traditional psychoanalysis (as discussed in Chapter 4A), as do new technologies, such as robotics, because they provide an escape route for flourishing subjectivities and offer new approaches to old ways – they displace and are not beholden to the signifiers of dominant powers that position subjects into strata. Guattari's notion of cybernetic machines could deterritorialise, or upend and refresh the systems of stratification, to liberate. Guattari theorises, 'I call machinic production—the revolution of computers, telecommunications, robotics, and so on'[824] because they can operate to emancipate from hierarchical structures. But these machinic productions, as with all machines, are double-edged swords, as they can fall either way, according to Guattari.

For Guattari, the possibilities for the transversal subjectivities of new technologies are contingent upon the proviso that they don't become overtaken by capital's systems of overcoding and territorialising machines, which capture technological landscapes and 'transform power relations radically and increasingly marginalize considerable segments of the population'.[825] He means that if

[819] Guattari, *Molecular Revolution in Brazil*, 1, p391.
[820] Guattari, *Molecular Revolution in Brazil*, 1, p32.
[821] Guattari, *Molecular Revolution in Brazil*, 1, p447.
[822] Guattari, *Molecular Revolution in Brazil*, 1, p210.
[823] Guattari, *Molecular Revolution in Brazil*, 1, p391.
[824] Guattari, *Molecular Revolution in Brazil*, 1, p32.
[825] Guattari, *Molecular Revolution in Brazil*, 1, p200.

machines fall under the sway of capital, they can exacerbate the divide between those who have and those who do not. Whether it is power, money, race, or culture, all types of productions, those who have will exploit machines under the pretext of capital to alter outcomes to serve their own interests. Those at the top of the hierarchy will ensure they have an unrelenting grip, with their insatiable desire to keep the working classes compliant (who shall remain voiceless, powerless) to enslave the have-nots in all the very dimensions that determine economic outcomes that always include the production of subjectivity.

As we have seen, machines (especially those of rupture) can be the working arms of transversality. Their heterogeneous nature can be composed of assemblages that include social, theoretical, economic, and political machines, among others. The characteristic of machines are their intrinsic drives (desires) and their ability to mediate semiotics. Machines articulate, cut, and control flows. Their ruptures can be spectacular forays for transversality that shatter hierarchies by incorporating connections to diversity. Machines can both indoctrinate or liberate subjectivities, depending on how they are territorialised or overtaken. Capitalist machines oppose machines with embedded transversality, as one dominates and captures, while the other liberates and enriches. Machinic ruptures are the mutant transversal representation of transversality that breaks free from machines of control. For Guattari, machines serve as a metaphor that decodes, depolarises, and objectifies the boundaries between the corporeal and the incorporeal, which are so distinct in traditional psychoanalytic therapeutics. This strategy enables full flights of heterogeneous connectivity and relationship building, with a processual nature, engendering flows that disregard stratified borders. This includes the flows of unconscious subjectivities that are constructed from semiotics. With great hope, it is possible to suggest that Guattari believes information machines, such as robotics and other similar technologies, could provide a machinic rupture and serve as the instrument for a revolution in subjectivity if left unfettered by dominant logocentric, phallocentric, capitalising, and racialising-colonial hegemonies.

The mechanicity of SRFs and third-thumbs: motors, batteries and sensors

The SRF (Supernumerary Robotic Finger) has many constituent components. These components are the assemblages of smaller electronic parts and the mechanical apparatuses integrated to make up the SRF mechanical function. They include servomotors, actuators, 'mechanism use of tendons, the

mobile pulley mechanism',[826] interfaces, batteries, sensors, and pneumatic components depending if it is a soft or hybrid-rigid SRF, a 'support base consists of two parts coupled with velcro strips to facilitate wearing the device',[827] haptic feedback devices such as the hRing,[828] and various types of EMG interfaces that control the 'motion of the robotic extra finger […] through gesture recognition'.[829] As seen in Chapter 3, SRFs come in various types, shapes, sizes, and configurations, depending on the combination of the above components and the researcher's idealised user's objectives and needs. Depending on these configurations, their functional abilities can vary accordingly. The figure below shows three examples of fully actuated SRFs: Figure 39 & Figure 40. Figure 41 shows an example of an underactuated SRF using 'cable-pulley mechanisms'[830].

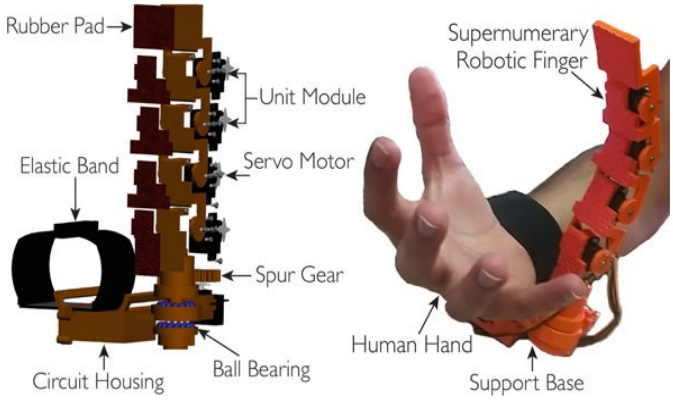

Figure 40-Robotic Sixth Finger showing some components by L.Hussain and D.Prattichizzo[831]

[826] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p11.
[827] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, p46.
[828] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, p86.
[829] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, p105.
[830] Hammond Iii, Wu, and Asada, "Variable Stiffness Pneumatic Structures for Wearable Supernumerary Robotic Devices," p206.
[831] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, p106 Figure6.9.

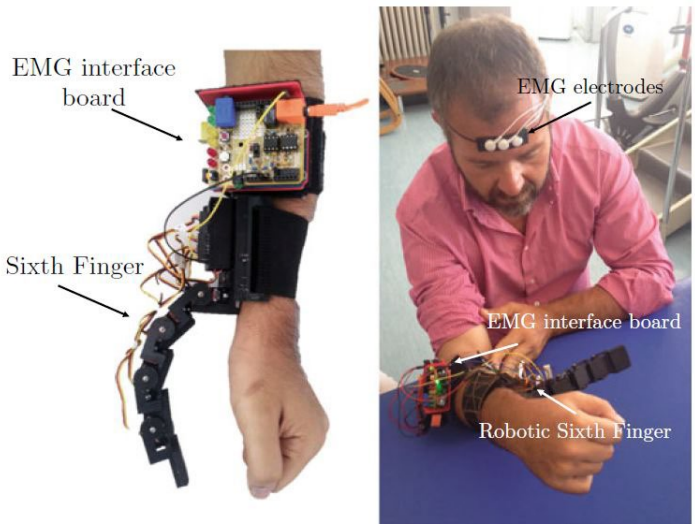

Figure 41-Robotic Sixth Finger showing some components by L.Hussain and D.Prattichizzo showing interface components[832]

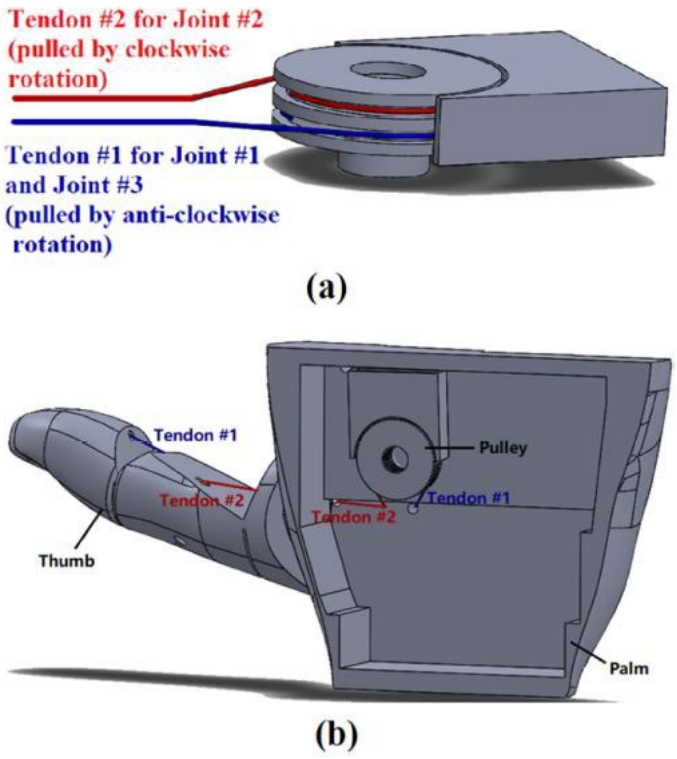

Fig. 3. (a) Concept of modality selection to separately actuate two tendon systems of the robotic thumb (b) the connection of the pulley/motor and the thumb (the tendons' routes inside the structure not shown).

Figure 42- Example of a cable-pully mechanism taken from Hao Zhou et al.[833]

[832] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, p32 Figure 3.4.

[833] Hao et al., "A Novel Monolithic Soft Robotic Thumb for an Anthropomorphic Prosthetic Hand," p605 Figure 3.

The 'mechanical components of the finger'[834] described by Hussain and Prattichizzo (Figure 39 and Figure 40) can be considered machines and mechanical systems simultaneously. Interestingly, although all the papers refer to the sixth finger as 'robotic', the terms 'machine' and 'mechanical' are rarely used in the discourse. Indeed, the line between a machine and a robot is rarely drawn. How many components transform a machine into a robot? How many machines might constitute a single robotic function? As Hubatschke suggests in 'How to Dance with Robots' 'technologies can always only be understood as part of specific machinic assemblages, which will open up the notion of technologies to focus on the combinations and arrangements they are part of and they can become part of.'[835]

SRFs are both machines and mechanical instruments that augment human capabilities. They possess a robotic machine's 'mechanical structures'[836] and design properties suitable for human interfaces. If we take the example of one paper, the paper by Liu et al., titled 'Otariidae-Inspired Soft-Robotic Supernumerary Flippers by Fabric Kirigami and Origami', all nine contributing authors to that paper are academics in mechanical engineering. All other authors noted on the papers in the SRF reviews tend to be researchers from fields such as mechatronics, engineering, robotics, electronics, and other related fields. This homogeneity of disciplinary skills makes their projects particularly focused on studies of machines. Thus, from this combination of mechanical and machinic focus brought to bear by the authors, questions are raised about how to view this work from any standpoint other than an engineering-based study of machines.

When we consider the mechanical and machinic aspects, we can safely say that the brain can be considered a machinic system due to its complexity and flexibility. This example, taken from Liao et al., illustrates the discourse on the interactions of the body and the mind, paying attention to the language that describes: 'Recently, the brain–machine interface (BMI) has been a wide appliance to control assistive robots.'[837] Liao et al. even go further than just correlating the brain and machine. Their reference to utilitarian tool-like reference to the application of an SRF controlled by the brain and its appliance using BMI or 'brain-machine' interfaces are terms that conjure the manifestation of mechanical (say the technological artifice), and machinic (the brain as a part of the technics of the machinic) assemblages that are ultimately viewed together via their varied connections as a type of Guattarian machine in their conjointment.

[834] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p3.
[835] Hubatschke, "How to Dance with Robots," p212.
[836] Hu, Leigh, and Maes, "Hand development kit: Soft robotic fingers as prosthetic augmentation of the hand," p27.
[837] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p267.

When Kielibal et al. refer to the brain's ability to adapt, control and integrate their third-thumb SRF device, their research refers to the brain's 'neural plasticity mechanisms'[838] as if it has a mechanistic fluid materiality blurring any boundaries between the territory of the brain and the machine, amalgamating new information as part of one continuity.

When Hussain et al. speak technically of components in SRFs, they refer to 'mechanical systems with a prevalent dynamics of elastic type'.[839] This means that when using actuators, the stiffness of the grasp and, thus the control through the actuation is less dependent on adjustments of the accuracy of the servo motors being precise with a response force needed for that grip because of the elastics nature of the dynamics of the gripper having more leeway for the motor to overshoot or undershoot. The characterisation of plasticity and elasticity in this discourse reveals how we see these systems when viewing the former and latter author's ways of referencing their SRF and the brain. In a more abstract comparison, the two descriptions are prototypical characteristics that make them comparable and compliant machines. That is, the brain has a certain level of 'plasticity', as does the mechanical SRF concerning its level of 'elasticity', making both equivalent in their levels of adaptation to their environment, simultaneously referencing them on a singular level of material functionality.

Another example of the discourse on SRF that uses very transferable terms is found in the following: When Shafti et al. want to upscale human motor coordination skills to coordinate the SRF, they talk about the foot being on the same level of 'biomechanical hierarchy'[840] as the hand for the control of SRFs. Shafti et al. also speak of other methods of controlling SRFs, including 'brain-machine-interfacing or cognitive interfaces'.[841] Therefore, we can regard both the human and the SRF as machines or mechanical devices interchangeably, not as equivalents but as assemblages of (mechanical) subsets of machines. Even when their state of hierarchy differentiates mechanical and machine, their conjugation ultimately alters their final function and reference, bringing them back to the idea of the Guattarian machinic because of the effect the latter has on the former. When we speak of subsets and hierarchies, we speak of different machines that comprise the SRF, such as finite state machines (FSM), which are subsets of actuators 'used to produce accurate and robust

[838] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p5.
[839] Irfan Hussain and Domenico Prattichizzo, "Compensating Hand Function in Chronic Stroke Patients Through the Supernumerary Robotic Finger," Biosystems & Biorobotics (Switzerland: Springer International Publishing AG, 2020), p31.
[840] Shafti et al., "Playing the piano with a robotic third thumb: assessing constraints of human augmentation," p7.
[841] Shafti et al., "Playing the piano with a robotic third thumb: assessing constraints of human augmentation," p7.

control'.[842] Such a hierarchy is developed by framing one system as a subset of another or seeing one system functionally subservient to a greater effect or outcome. Habitually, this makes sense. It's a little like seeing the human body as a set of minor systems that necessarily compose the major functions. We know, however, that even a minor system might control the whole and make the entire body subservient to it. When I experience an allergic reaction to a peanut, my whole body becomes a peanut-induced death machine, and neither my brain, my circulation system, nor my sense of touch dominates the cells and proteins of my immune system. In the SRF, there are other machines such as 'threading machines' and 'nylon machine screw' and many, many more machines that form the subset of SRF assemblages.[843] And yet, if a single nylon screw breaks, the whole SRF collapses. Thus, the biomechanical hierarchy is unresponsive to actual hierarchies under such terms. Therefore, where every subset and set is dependent on one another in such an interdependent way, the components of any assemblage, computer, machine, car or any other technological device fall under the cover of the machine. In an assemblage of components, each subset and part mediates the flows that make the machinic in the SRF possible. This is important because it supports Guattari's view that machines in transversal mode are liberating, creating new potentialities for functioning SRF machines, and is equally applicable to subjective-semiotic-mechanical-human-SRF-augmentive machines. That is a machine of human relatedness to non-human elements, the sum of its collective human and technological assemblages that alter subjectivity so deeply at the unconscious level.[844]

Taking a closer look at our example of the FSM (finite state machines), we see that the machines' connectivity operates at a level of abstraction, where human gestures are coded and decoded into machinic signals (see Figure 42). The SRF comprises many smaller machines, all of which are assembled into a larger unit called the SRF or a third-thumb. The abstract nature of the machine is so characteristic of the immaterial nature all machines, including the subsets of the SRF devices and equally theoretically when referencing Guattari's concept of the facets of 'abstract machines of subjectivation' - that is, the machines that produce subjectivity 'through the media, magazines, films, and so on'.[845] Likewise, I propose we see the biological body from the perspective of the comparative language used. The brain has cortical[846] subsets and networks of circuitry called neural networks. As in the example above, subsets are not always subordinate to their parent sets. They

[842] Setiawan et al., "Grasp posture control of wearable extra robotic fingers with flex sensors based on neural network," P2.
[843] Hammond Iii, Wu, and Asada, "Variable Stiffness Pneumatic Structures for Wearable Supernumerary Robotic Devices," p211.
[844] Guattari, *Molecular Revolution in Brazil*, 1, p353.
[845] Guattari, *Molecular Revolution in Brazil*, 1, p299.
[846]Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p14.

sometimes might control the whole and make the entire body subservient to it. We can think of the body, with its biomechanics, as comprising a cable-pulley mechanism system that it wishes to conjugate with, namely, the conjugation of orders comprising muscles with the biochemical systems that activate them to act upon the SRFs' cables and pulleys (see Figure 41).

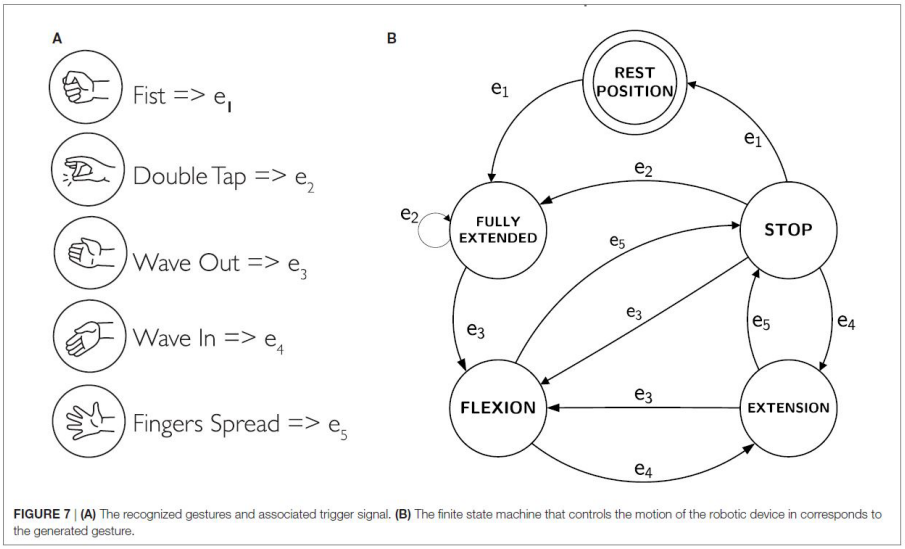

FIGURE 7 | (A) The recognized gestures and associated trigger signal. (B) The finite state machine that controls the motion of the robotic device in corresponds to the generated gesture.

Figure 43- Abstraction of recognised gestures into signals for finite state machine control from Hussain et al.'s paper on EMG interfaces[847]

Shafti et al. also say, '[w]hile extensive research has been conducted on the mechanical design, interface, and control of supernumerary robotics, there is a gap in understanding the role of human motor control in the success and adoption of these robotic human augmentation systems.'[848] This statement demonstrates a drive to understand human motor control, which is expected to be integrated into the SRF mechanical design in the future. The interchangeable linguistic nature of terms such as motors, mechanical, plasticity, mechanisms, and machinic that simultaneously describe the human and robotic are a marker of how we see these systems merging and biologically conjugating.

The term biomechanical may cease to be descriptive, as everything is eventually seen and converges towards the machinic. As these concepts integrate theoretically and semiotically, augmentation brings two machines into contact with one another, making integration seamless and allowing them to be indistinguishable from one another despite their variations as subsets. The flows will transversally cross the biological boundaries to the machinic in such superfluous ways, creating

[847] Hussain et al., "An EMG interface for the control of motion and compliance of a supernumerary robotic finger," p7.
[848] Shafti et al., "Playing the piano with a robotic third thumb: assessing constraints of human augmentation," p2.

redundancies of connections that will create a level of vitality and creativity. Eventually, we shall have one machine with subsets of assemblages containing biomechanical and robotic machines when the variety of those subsets interface in such complex ways that distinguishing their differences may be unimaginable. These indistinguishable beginnings are in the order of the ideas of machines that Guattari has in mind. The surge in creative ways to exceed habitual logic will give way to desires, thus replacing logocentric and phallocentric thinking that produces hierarchical value systems. The new possible ways of constructions of the self and connections to others will eventuate as a result in the same order as the examples given here: even more intensely when the ideas take hold, merge and grow with other theoretical, ontological, and abstract machines of the same transversal nature that potentially can configure with other technologies. As suggested by Guattari in the discussion of the potency of the idea of the machinic above – it is by order of transversality inserted in the processes and technics of augmentation that contain ways of communicating through abstracting connections that pay no regard to hierarchies that displace connections beset by divisions constructed through class, age, race, money, sex, sexuality, gender, culture, ability, disability and so on that the new creative subjectivity will emerge collectively.

But of course, the machines of the SRF are not purely machinic but also fall prey to the mechanical flows that are not just theoretical; they have a 'mechanical/electrical connector design' and, thus, are accommodating of electricity flows that surge through these systems. These convey 'Electromyography (EMG) control'[849] signals for interface and supervision of SRF, such as in the example of Hussain et al.'s eCap[850], reviewed in Chapter 3. These flows enable machines to coordinate and communicate with one another, exchanging signals and information between human and robotic systems. The flows of one machine, whether mechanical or electrical, will eventually merge with the biomechanical neuro-electric, making flows between machines more fluent in the flows of transversal thinking that have the power to abstract signals, thoughts, messages, communication, and ideas that do more than animate and SRF. Rather, they shall simultaneously animate the potentiality of machines within the context of subjectivity.

Examining the SRF discourse, we can observe how the machinic and mechanical vocabularies permeate both descriptions of robotic components and human biology, creating a linguistic terrain where the boundaries between human and machine become significantly blurred. The biomechanical hierarchies that initially appear to structure these relationships reveal themselves as

[849] Hussain et al., "A soft supernumerary robotic finger and mobile arm support for grasping compensation and hemiparetic upper limb rehabilitation," p5.
[850] Hussain et al., "A soft supernumerary robotic finger and mobile arm support for grasping compensation and hemiparetic upper limb rehabilitation," p5.

non-hierarchical interdependencies, where even the smallest component can determine the functioning of the entire assemblage. As SRFs and third-thumbs continue their development, we witness the early manifestations of Guattari's transversal machines—systems that liberate through their indifference to established hierarchies. The conjugation of human motor control with robotic assemblages suggests a future where the biomechanical and machinic become indistinguishable, potentially generating new forms of subjectivity. Through these flows of transversal connections that abstract signals across heterogeneous components, we may discover possibilities for creative reconfigurations of subjectivity that transcend traditional logocentric thinking, ultimately transforming how we construct the self and connect with others beyond established divisions of class, race, gender, ability, and other categorical limitations.

Machinic ruptures and the third-thumb

Revisiting Rolnik's distinction between the machinic and mechanical in describing Guattarian ideas of machinic is important to the propositions I am about to make. (At the risk of repetition, but) to remind us, Rolnik says:

> Machine (machinic): Here we distinguish between the machine and mechanics. Mechanics is relatively self-enclosed; it only maintains perfectly coded relations with exterior flows. Machines, on the other hand, considered in terms of their historical evolution, constitute a phylum comparable to those of living species. They generate each other, select each other, or eliminate each other, bringing out new lines of potentialities. Machines in the broad sense (i.e., not only technical machines, but also theoretical machines, social machines, aesthetic machines, etc.) never operate in isolation, but by aggregation or assemblage. A technical machine in a factory, for example, interacts with a social machine, a training machine, a research machine, a marketing machine, etc.[851]

First, let's examine Rolnik's explanation. Rolnik here suggests that the mechanical is less dynamic than the machinic because it lacks transversal flows and relations. When we relate the mechanical nature incorporated in the SRF, we can say that its hierarchically organised, rope-and-pulley systems with motors that work to open and close the finger are very closed-off systems in relation to exterior flows due to the lack of dynamism. That is, the rope and pulley have only one connection, and that is to close and open based on the directional movement of the motor. It is a very isolated system, coded to perform two simple tasks (see Figure 42). It is a closed-off system that offers nothing more than a dichotomous circuitry for opening and closing. As a system, it lacks the potential for other systems to integrate with it and perform more creative acts until we combine it with systems that

[851] Guattari, *Molecular Revolution in Brazil*, 1, p466-67.

open it up to other flows. When we consider it as a mechanical system incorporating computer circuitry such as the finite state machine and other machinic systems that have been described as controlling its torque, motion, and grasp capabilities, it suddenly becomes a very complex system with the potential to evolve. The evolution stems from the dynamics of its functions, inputs, and outputs, which are responsive to human interfaces that interpret and abstract bodily gestures and affective human response contingencies. The simple mechanical body of the SRF is now part of a complex set of relations that can respond to change as it grows to incorporate ECG interfaces and the technologies already mentioned in Chapter 3, which pick up the body's neuroelectrical responses and interface with them. Eventually, this will include technologies such as artificial intelligence. The increase in complexity becomes exponential, as does the potential for transversality, with the introduction of newer, improved technologies such as BMI systems, which were also discussed in Chapter 3. Suddenly, we have complex mechanical systems that start emerging as assemblages of machinic order, blurring the technological and theoretical boundaries as we become *techno-augmentative* human-machine instances. In this way, we see a dynamic system that is being transformed into a human-brain-machine and a mechanical-body-machine, a window-sky-machine, which brings joy by fulfilling our desires.

With the addition of sensors and human sensory capabilities, we have a whole new network of ways to perceive and understand the world, extending beyond the machinic to the affective level. We discussed how Guattari defines affect in Chapter 2. The approaching subtleties of flows of information and sensation towards our now expanded sense of body form a very complex traversal connection of the machinic order. The incorporation of sense allows the affective flows that incorporate Guattari's machinic ideas on changing the 'process of perception and sensibility'[852] that mobilise completely new paradigms. These new paradigms incorporate an information machine with the abstract capacity of the human body and mind, as well as a machinic source that feels, hears, sees, smells, and interprets the sensations of the world through a computer language integrated with the body. This expansive environment isn't just embedded in the landscapes of the territories, flora, and fauna, but it's also a complex interplay between one and many, and many and one. It also incorporates the detailed components of its environment. It includes the economic machines, the political machines, the media machines, the social machine, the historical machine, window machines, and a myriad of other types of machines via a more critical analytical process of digestion of subjective production because of the personal cross-referencing of transversality that is experiential through real relationships rather than secondary, stripped back information and slogans

[852] Guattari, *Molecular Revolution in Brazil*, 1, p43.

of the socio-political and economic discourse of capital. These are the ruptures that the machinic can provide in the state of *trans-augmentative techno-subjectivities*.

Semiotics of the SRF machine

Second, let's discuss the underpinning of Guattarian analysis of transversality, which represents another subtle shift in the machinic systems. By revisiting the semiotic machines described earlier, we can now examine the discourse in the field of SRFs. This semiotic exchange may provide insight into the future of a third-thumb, considering the contingency of the earlier semiotic distinction between Rolnik's concepts of *machinic* and *mechanical*, which describe the intersection of mind and body concatenation in augmented-SRF-machines. As discussed, the interchanging nature of the language used to describe these two subjects —the notion of Guattari's machinic and the mechanical nature of SRFs — is bridged by a transversal consideration of the nature of machines. The ability to objectify machinic thinking is a way for Guattari to release the subject from the polarising nature of the politics of subjectivity, making them a disembodied machine of desires. The processual and analytical component of machinic thinking enables us to capitalise on opportunities to understand the potential transversal connections, tracing the complexity of flows through their interactions with other machines (desiring machines making cross connections). Those machines could originate from a mechanical configuration, but can be traversed into the machinic through transversality. By tracing the processual nature of these connections of flows between machines, Guattarian machinic systems focus the flows of influences on the subject and mobilise the subject's activism to exercise self-sovereignty over mind and body. The mechanical SRF, augmented by the body, is the genesis of this process. It gives way to becoming and transforming into the machinic, exemplifying transversal reconfiguration. In this process, there is a recognition that machinic desires can connect and be ethically responsive (as described in Chapter 2), and a more critical understanding of their expressions while being analytical about the altering character of the semiotic machines (that bombard the subject). After all, semiotics is the driver of subjectivity.

The words 'mechanical' and 'machinic' now take a dynamic turn in my discourse, pointing to a level of transversality that can liberate and construct a thriving subject in a flourishing, free society. Yet we know that equally, the SRF machine can subjugate the user through capitalistic subjectivity. The ability to note the capacity of semiotics to mediate the expressions of subjectivity, which can be considered in Guattarian assemblages of enunciation, is as critical to transversality as it is to schizoanalysis in the field of SRF. The nature of machinic systems renders the structural dynamics between the politics of subjectivity, economics, social constructs, and various environmental subsets

of assemblages more transparent, potentially freeing us from the machinic assembly line of capitalistic subjectivity, a critique Guattari strongly advocates. These assemblages, produced in the process of augmenting a third-thumb, can traverse issues of identity, body morphology, and social and political discourse that determine subjectivity and derive relations to justice and autonomy. Therefore, how we speak about SRF is important because it reflects our state of mind as researchers and users. Without their machinic ruptures that cross into territories of subjectivity, the techno-augmentative interaction with its various social machinic components—both organic and non-organic — would make evolutionary changes nearly impossible. Here, I am referring to our desires, fantasies, and dreams for a paradigmatic shift towards the embodiment of a third-thumb of an SRF. These ruptures in the semiotics of language are indicative of changes in thought that foreshadow changes that make us adaptable, resilient, and interconnected. The semiotics ruptures or lines of flight away concerning surrounding discourse on the SRF benefit communities by providing information about the types of free societies constructed through the use of SRF, which can help marshal subjectivity out of its habitual cages constructed by dominating powers. By examining the SRF as a human-body-mind-SRF augmentation, we can shift the discourse on work and capital to focus more on pleasure and desire. In a ripple effect, the subject's changes also challenge other norms across all levels of thought on ideas that withhold and constrain desires of subjectivity. The shoots of transversal relations, which are part of our healthy systems of assemblages of enunciation, express and embody these collective narratives of the SRF with their ruptures readily able to connect to other sprouts of hope and opportunity found in new types of relations. This journey began with a break from normative habits and the courage to integrate technology, and it will continue until a viable third-thumb is realised and becomes part of our everyday lives. This courage to dare undulates through the varied relations of machines, connecting them to other machines and the interrelation of desiring machines. This includes the machines of all types that connect technological machines, while moving subjectivity closer to other machines of desiring flows, encompassing aesthetic, theoretical, economic, anthropological, sociological, biological, material, ethological, and other domains – all potentialities of machinic transversality and their semiotics.

The semiotic discourse surrounding SRF technologies reveals the fault lines where machinic transversality might rupture capitalistic subjectivity, offering glimpses of new desires and embodied potentialities beyond established morphological constraints. Through these ruptures in language and technology, we might glimpse a new assemblage of relations (a collective assemblage of enunciation) where the third-thumb becomes not merely a mechanical augmentation but a machinic deterritorialisation of the body itself, creating novel flows between heterogeneous registers of human and non-human becoming.

The realisation of transversal ruptures

Third, as soon as mechanical systems incorporate complex (what I call abstracting) systems, such as the example of the finite state machines and similarly BMI, we reach the level of correspondent flows to the exterior that work in multivariant ways that exceed the 'perfectly coded relations'[853] described by Rolnik. I see the argument before you regarding the expansive nature of SRF augmentation with bodily senses and intelligence as part of a broader paradigm of the third-thumb that incorporates Rolnik's mechanical system, shifting it towards the machinic, if infused with transversal complexity, which in these cases it is. The mechanical serves as a starting point for the machinic, particularly within an integration and augmentative system that expands, creating more points of connection, incorporating additional systems, sensing more things, and generating creative outputs. This is due to the new connections and messaging pathways created, as well as the propensity for self-reconfiguration incorporated into the augmented machinic systems at SRF and the mind-body levels. It is a powerful juncture at the intersection of the social, incorporeal, and corporeal (encompassing both organic and inorganic). The direction of SRF machinic assemblages that I have traced and proposed here specifies levels of embodiment of the brain through the SRF, utilising brain plasticity and material elasticity.[854] Plasticity and elasticity become examples of Guattari's machinic when they are placed on a level of equivalence in machinic systems, facilitating the distribution of inputs and outputs through varying interactions in line with sensing changes in their context or environment. This dynamic adaptability of concurrence in both the SRF and the human brain creates a system that can respond to its environment in transversal ways, incorporating changes in expression, perception, and user neuromuscular reflexes to respond to ontological pleasures and desires.

For example, where SRF are concerned, the augmentation of the developed idea of the machinic system also embodies an ability to grasp objects in ways that alter the subject's relation to objects and the world and, where a sense of the world is transfigured. In turn, where the SRF alters itself through its mechanical elasticity and the body's brain plasticity, this assemblage is in a mode of reconfiguring self-regulation, which is part of the ideas of Guattari's transversality. Therefore, the idea of an SRF responding to the user's desires to mobilise the SRF to move and grasp in certain ways that alter the subjectivity is core to transversality. However, it is not just the nature of transversality itself that is key. Rather, it includes the ruptures that rhizomatically liberate the subject into other ways of being, experiencing, seeing, feeling, and understanding.

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[853] Guattari, *Molecular Revolution in Brazil*, 1, p466-67.
[854] Hussain and Prattichizzo, "Compensating Hand Function in Chronic Stroke Patients Through the Supernumerary Robotic Finger," p31.

Plasticity, elasticity, compliance, and adaptation are the order of machinic ruptures that locate transversality. This dynamism makes the human-machine coupling, which I term the *techno-subjectivity* of the SRFs, a key transversal movement. It crisscrosses the boundaries of biological and technical stratifications, based on highly differentiated systems that express pleasure and desire.[855] Thus, the SRF might cease to function as a mechanical system of rope-and-pully and motor and thus eventually configures the beginning of a connective machine, a desiring machine, an information machine, and so on, that expresses the new processes of subjectivation that create a unique, singularized subjectivity in Guattarian terms (as introduced in Chapter 2). In this way, the augmentation of a third-thumb becomes its technics that provides an escape route for flourishing subjectivities through transversality, facilitated by the various assemblages and connections of flows, as outlined in Guattarian machinic propositions. These propositions incorporate highly differentiated notions of desire and their connection with the social and collective unconscious.

Rolnik's the factory and the human

Fourth, if not through integration and augmentation, the interjection of one machine (say, the body) over another machine (say, an SRF) or vice versa is another form of machinic interaction without direct intervention. A machine far from the body, a machine displaced in space from the body, such as a remote SRF (yet full embodied), as discussed by the ideas proposed by Prattichizo et al. (discussed in Chapter 3), is in the realm of ideas of the global abstraction of that machinic system interacting with other environments that intensifies the transversal emergence beyond its immediate context. In the example used in this chapter of a tree, we referred to it as being planted deep in the earth, interacting and relational to all its environmental contextual situatedness. These contextual factors would situate it in relation to various aspects, such as the richness of nutrients in the surrounding soil, the ambient temperature of the climate around its canopy, the direction the sun faces, the aspect, and the microclimate of its surroundings in the landscape. Now imagine if that tree could access another microclimate and other nutrients and sense the contexts of other trees in the landscape that are far from their own, such as in the desert, the rainforest, or the tundra. In such a case, this tree becomes attuned to the planet's climate and can be more readily responsive to changes that foreshadow the coming needs for adaptation before the shock of any sudden change. The tree's relatedness to its situation is not confined to a mechanical sense but is truly transversally and globally machinic, as it connects many points of juncture, not just locally. The global relation of an SRF that is situated far from the body is a machinic relation that is sensorially connected. Guattari

[855] Guattari, *Molecular Revolution in Brazil*, 1, p353.

would describe it in similar ways when he describes the relationship between the subjectivity, the machine, and semiotics that impact the opening of boundaries to transversality in the following passage,

> Quite the contrary: the junction of informatics, telematics, and the audiovisual will perhaps allow a decisive step to be made in the direction of interactivity, towards a post-media era and, correlatively, an acceleration of the machinic return of orality. The era of the digital keyboard will soon be over; it is through speech that dialogue with machines will be initiated - not just with technical machines, but with machines of thought, sensation, and consultation…. All of this, I repeat, provided that society changes, provided that new social, political, aesthetic and analytical practices allow us to escape from the shackles of empty speech which crush us, from the erosion of meaning which is occurring everywhere.[856]

Guattari's explication is related to the connectivity through the relationship between the machinic in subjectivity and its aesthetic and ethical paradigms, which means there is an intrinsic coordination in transversal machinic assemblages.

Revisiting the distinction between Guattari's and Rolnik's machinic and mechanical systems is useful when discussing the SRF and the paradigm of a third-thumb. The distinction between the two terms is drawn out by Guattari's opening passage to the section of machinic and the mechanical above, where he says, '[w]hen I say "machinic," I am not referring to the mechanical, or even necessarily to technological machines. Technological machines exist, of course, but there are also social machines, aesthetic machines, theoretical machines, and so on.'[857] Even if I cannot convince you to consider SRF as machinic (in the first instance) but instead a purely mechanical system, disregarding the technics that allow them to interface with the human mind and body as discussed, they remain equivalent to Guattari's '"concrete machinic processes" (technical machines, economic machines, etc.)'[858]

In Rolnik's example, the simple feat of people interacting in a factory (page 209) setting with mechanical contraptions (consisting of mechanical cogs and gears) produces something germane to the machinic. One exerts influence upon the other and can alter the relation of the other by their mere interaction or interruption, remembering that machines never operate in isolation and that they cut and redirect flows. That makes the factory cogs and gears and their human counterparts a machinic relationship. The interaction between SRF and humans is an even more intense example of a human-factory machine, as it represents a more tightly bound complex relation between the body,

[856] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p97.
[857] Guattari, *Molecular Revolution in Brazil*, 1, p353.
[858] Guattari, *Molecular Revolution in Brazil*, 1, p465.

mind, and SRF machine, exceeding any notional relation. This metaphor also foreshadows the dangers of capital to subjectivity, which have already been discussed in Chapter 2 concerning the surplus value of labour in the operation of IWC. After all, the factory is the *mise en scene* for the labour machine. Other examples included Liao et al.'s descriptions of BMI-controlled SRFs, in which they refer to the 'brain-machine' interactions that have already been discussed.[859] Leigh et al.'s example of 'body-integrated augmentation' directly equates the Heideggerian idea of '*ready-to-hand* and being *present-at-hand*' when referring to '*machine-as-a-body-part* and *machine-as-an-interface*'.[860]

This case also supports my growing argument that SRF is machinic in Guattarian terms, despite having a canny resemblance to Rolnik's definition of the mechanical. I propose that we consider the SRFs as machinic, as the body operates this mechanical device, exerting the variability and opportunities offered to transversal machines, regardless of their level of sophistication. This perspective places them at the intersection of social machines, theoretical machines, and machines that can think and be creative when augmented with humans. This type of combination is a mixture of the political and social machines, crossing the concrete machinic process of the SRF, which lands in the strata of the Guattarian mechanical/machinic mix that is highly transversal and active. It is worth considering that machinic systems interject into the mechanical system, and their dilution of the mechanical may provide an escape into transversality and social freedom. I suggest that this is because of the novel ways the SRF intersects and becomes political, societal, and economic in its emplacement upon the body, which impacts subjectivity and the landscapes of life. The revolutionary and techno-augmentative nature is disruptive to the normative understanding of subjectivity, whilst it projects the body as a site of activism within society. As with the philosophical consideration in this thesis, the theoretical machine of the augmentation of a third-thumb inspires and provides a transversal relation to all modes of thought and life. This alternative way of viewing subjectivity has the potential for the type of Guattarian machinic ruptures discussed earlier. Still, this time, it is impacting the wider conception of culture, economics, class, sex, identity, the environment, and many more areas of life, giving rise to a distinct political discourse. Through this machinic/mechanical rupture, a change in the status quo may occur, even one of an evolutionary nature for the body. However, *ipso facto*, (let us remember Guattari has warned us that) machinic systems can also fall captive to dominant forces of logocentric, phallocentric, colonial-racialising

[859] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p267.
[860] Leigh and Maes, "Short Body Integrated Programmable Joints Interface." p6056.

dominance that reinforce the status quo (for example, under capital) if the SRF is not carefully negotiated in an inclusive way that provides equal access and justice for all.

Conclusion

When embodied, the mechanical and machinic systems that comprise SRFs and third-thumbs, thus have immense repercussions for the body, its politics, and society. Breaking from the model that represents the body schema is an abandonment of the mainstay of the body as it is habitually regarded. In our culture, any divergence from this body schema is a flouting of mechanical thinking habits (two-dimensional thinking) found in literature, the arts, and history. The machines of literature, poetry, and the arts romanticise the body's configuration in the normative ways we have habitually come to recognise them (a type of contradiction of terms). A mechanical (as in terms of SRF) or machinic rupture (in terms of trans-augmentative adaptation to SRFs) in the order of augmentation of a third-thumb would represent the transition to unfamiliar body shapes and body schemas, most probably operating vastly differently— articulating transformations in broad politics, economics, and societal discourse with the body in fields such as writing, architecture, painting, playing the piano and even how we hold tools or eat, and the ways we greet each other. This will lead to other alterations in the great machines of production (capitalistic subjectivation), the machines of culture, and an understanding of identities, ultimately bringing about social change. The machinic dimension to the mechanical conjoint of the machinic order, that is, the augmentation with SRFs, would sweep up and change all the aesthetic, literary, artistic, socio-political, and economic machines (and their mechanical counterparts) that comprise our culture to free us from all its constraints that inhibit subjectivity and the psyche. Thus, the augmentation of the hand with an SRF or a third-thumb would be the local transformation of the hand, equally as it becomes a global site for a true machinic transformation through transversality.

Chapter 4C - Transversality and transmission in SRFs via group therapeutics

Introduction

In consideration of Rolnik and Guattari's theory of subjectivity and the technical particularity of SRFs this chapter will explore the idea of group therapeutics and its various modalities, before using it to analyse how these dynamics are operative in the field of SRF. This includes understanding how *subject-groups* and *subjugated groups* operate in society and their expressive semiotics in the transmission of messages and information. In this dissertation, the concept of transmission takes many forms, whether it is the transmission of electrons or the transmission of epistemology. They are both the flip side of the same coin, as far as I am concerned, when examining their psychoanalytical impact on a group or their material outcomes on the development of technologies and technics in the field of science. Let me briefly define these two groups. *Subject-groups*, in Guattari's theory, are characterised by their ability to manage both external determinants and their own internal law. Subject-groups possess a certain autonomy and self-determination within collective dynamics. They maintain an awareness of their own finitude and temporality, embracing their processual nature rather than seeking permanence. They actively engage with and transform their social conditions rather than being passively defined by them. Their subjectivation processes remain open to new possibilities, connections, and creative becomings rather than being fixed in rigid structures. The term *subject-group* was a term Guattari utilised in his earlier work, which explored group therapy. Over the course of a decade and a half, he gradually shifted to using the term 'process of singularization' instead, which is heavily used in the *Molecular Revolution in Brazil*. We have explored this process in detail in Chapter 2. However, because I will be heavily referencing his earlier work on group therapy in this chapter, I will use the term subject-group and its binary opposite, which is *subjugated groups.*

Meanwhile, *subjugated groups* are individuals (the concept of the *individual* was discussed in Chapter 2), manipulated by external determinations and dominated by their own internal laws (particularly through superego functions). Subjugated groups tend to be organised hierarchically, with members accepting established roles and identities imposed upon them. They often operate through mechanisms of alienation, where members' desires are subsumed under the group's dominant ideology. Rather than expressing their own autonomous project, subjugated groups

primarily serve to perpetuate existing power structures and established modes of subjectivation. In political contexts, subjugated groups often manifest as bureaucratic organisations that reproduce dominant social relations rather than transforming them.

In the previous chapters, I introduced several complex ideas that form the basis of Rolnik and Guattari's conceptualisation of subjectivity, as per *Molecular Revolution in Brazil*. I traced how transversality opens up the therapeutic concepts of transferences beyond just 'mythical Mommy-Daddy'[861] dyadic evaluations, as described by Deleuze in his Preface to Guattari's book *Psychoanalysis and Transversality*. The discourse on transversality encompasses many concepts introduced in Chapter 4A that relate to and bridge how transference was incorporated into the socio-political discourse through a schizoanalytical model of understanding, which considered desire, semiotics, and the concept of the rhizome across society, politics and economics. In Chapter 4B, the machinic idea that is core to conceptualisations of a subject's relation beyond the simplistic image of the human body (or the internal mechanics of the psyche) was explored in detail. These concepts all relate to how the augmentation of an SRF impacts subjectivity in techno-subjectivities. I also explained in Chapter 4A that Guattari utilises Schotte's ideas to bridge the transference and the broader social field of language, thereby linking transference, language, and its relation to 'transference as it manifests itself in the group or institution'.[862] The inclusion of groups and institutions, which is the focus of this Chapter, aims to explain how Guattari's therapeutic use of these elements helps elucidate transversality in terms of schizoanalysis, which also encompasses the influences of environmental and circumstantial factors on subjectivity. By incorporating these concepts into the analysis of SRF and its discourses, we can gradually develop a theoretical understanding of how SRF augmentation and techno-subjectivities operate within a broader socio-political and economic context.

In this Chapter, I shall explore how subjectivity is understood through transversal unconscious discourse disseminated between *groups* and *institutions*. I will build on Guattari's psychoanalytical processes from Chapter 4A, utilising Guattari's extension of transferential phenomena into the social field through groups and institutions. I shall explain how Guattari understands the problem of the transference between individuals, groups, and institutions. I shall also explain how Guattari perceives highly stratified societies and subjectivities in states of capture and how transversality can operate to dismantle them through group dynamics. I follow this up with a discussion on how overcoming these barriers can free subjectivities to operate in the relationships between various

[861] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p8.
[862] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, 76.

social groups, establishing messaging systems that incorporate diversity while de-escalating divisions and increasing understanding. These processes include Guattari's views on the undercurrents of groups and institutions that have a bearing on the 'infrahuman, intrapsychic, infrapersonal nature'[863] of subjectivity that help them through the process of singularization and becoming autonomous. I shall then turn my attention to the field of SRFs to uncover a unique but important idea in the term transmission. I am interested in the meaning of the term and its application in the field of SRF. I also consider and examine the use of the term 'transmission' as used in some technical examples found in the discourse on SRFs. After that, I will compare Guattari's ideas on groups and institutions, as well as how messages and information are transmitted through these groups and institutions, to produce and affect subjectivity in a comparative analysis. The transmission of communications through groups and institutions is considered in light of the Guattarian concept of group therapeutics, combined with several ideas from previous chapters. These ideas aim to construct an argument for transversal strategies to address and highlight the issues that complicate communication among and from researchers, as well as the relationship between the technics of transmission technologies and the pathways and byways of subjectivity.

The subject-group (or group-subject[864] or the process of singularization) and subjugated groups (or subjected groups)

Guattari problematises transference into the wider social field through complex exchanges amongst subjectivities that can be expressed between *groups*, *institutions*, political parties, and the symbolic roles individuals play in them. This awareness of how all these settings interact with one another is derived from Guattari's objective, which is to elucidate how subjects and collectives can negotiate normative expressions. These normative expressions often reflect the production of subjectivity[865] because they are part of the processual assemblage in which they are constructed. According to Patrick Ffrench, Guattari's concept of 'the group', 'the organisation' and 'the institutions' is a concept borrowed from Marxist and Hegelian philosophers, including Jean-Paul Sartre.[866] From this explanation of its derivation into Guattarian sillogisms, it is possible to understand why Guattari

[863] Guattari, *Molecular Revolution in Brazil*, 1, p43.
[864] Guattari changes the term itself to group-subject to subject-group during the later years of his writting. In this early work such as here Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p13. As he develop shis ideas on groups he started with the term group-subject later moving to subject group in his later writtings such as in Guattari, *Molecular Revolution in Brazil*, 1, p62.
[865] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p76-79.
[866] Ffrench, "Guattari's Therapeutics: From Transference to Transversality," p219.

undertakes to centre the group struggle as the dynamic that contains the tension of subjectivity. By removing the focus on the individual, Guattari attempts to shift the focus onto the psychodynamics that mobilise group struggles and the processes of singularization (discussed in Chapter 2). By extension, we can clarify the gravity of groups for Guattari, drawing on Storm Heter's ideas about Sartre's contention that 'group struggle is the animating principle of human history.'[867] This may be why Guattari, a militant Marxist, uses the concept of *groups* to express the drive for the autonomy of subjectivity through group struggles and activism.[868] This idea is supported by comments from Gilles Deleuze, who describes Guattari as a Marxist, a 'militant political activist and a psychoanalyst' in the preface to Guattari's book, *Psychoanalysis and Transversality: Texts and Interviews, 1955-1977.*[869] It would be safe to assume then that Guattari understood the value of *groups* and *institutions* as structures that can be analysed to understand the expressions of groups containing animating forces at the intersection of the collective states of the subjective unconscious and the translation of the extrinsic pressures of its contextual politics. Given the left-leaning social and political character of Guattari's analysis, it is not surprising that Guattari finds insights from such group struggles so appealing.[870] In addition to his Marxist empathy and ideas on institutional psychotherapy (discussed in Chapter 2), Guattari is constructing a complex synthesis of ideas on how societies function and their impact on the production of subjectivity. According to Guattari, it is 'possible for *groups* to dismantle the production of dominant subjectivity'[871], freeing them from the pull and push of being a subjugated group: that is, enslaved to the governance of dominant hegemonies.

Guattari's work at La Borde taught him that transversality could not only be opened up between the individual and the analyst but also between the wider collective, such as the subject-group and the subjugated group (or, as he often also uses the term, the *subjected-group*), in broader society.[872] This movement of analysis between *groups* doesn't imply that one *group* acts as an analyst, analysing the other. It suggests that the dynamics of exchange of messages found in transference and transversality can be identified between groups as a more potent reading of subjectivity through

[867] Storm Heter, "Sartre's Political Philosophy," in *Internet Encyclopedia of Philosophy* (East Stroudsburg University, 2024). https://iep.utm.edu/sartre-p/#:~:text=Sartre's%20dialectical%20theory%20of%20society,animating%20principle%20of%20human%20history.
[868] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[869] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p7.
[870] Guattari, *Molecular Revolution in Brazil*, 1, p196.
[871] Guattari, *Molecular Revolution in Brazil*, 1, p170.
[872] Chapter called The Group and the Person in Guattari, *Molecular revolution : psychiatry and politics*, p24-44.

schizoanalysis. Groups can provide more fertile ground for the therapeutic act of uncovering and interpreting messages.

I would like to take a moment to provide some background on the terms used to describe groups. In his book *Molecular Revolution Psychiatry and Politics*, written five years before the publication of the essays in *Psychoanalysis and Transversality: Texts and Interviews 1955-1971,* Guattari interchangeably used the terms 'independent groups and dependent groups'[873] instead of *subject-group* and *subjugated-group*. He also vacillates between the terms *subject-group* and *group subjects* as explained in the footnote to the title of this section. I shall henceforth use subject-groups and subjugated groups. The meanings of the terms *subject-group* and *subjugated-group* are not fully elucidated, and their meanings have evolved in line with Guattarian thought. We can think of the subject-group (the processes of singularization, becoming oneself — referred to in Chapter 2) and the subjugated-group (the modelled individual or individualised at the behest of IWC) as social constructs of collective expression that determine the tension in human relations. These tensions are shaped in the foundation of political groups and government institutions, particularly affecting an individual's relationship and voice within the joint expression of desires in a determination for liberation concerning the group's struggle. It is not only a Marxist struggle, but a struggle that encompasses many battlegrounds, including issues of identity, recognition, equity, autonomy, diversity, and economies of desire, which are crucial to free, flourishing societies and the state of subjectivity. In his Brazilian journey, Guattari refers to this type of struggle as a struggle in 'politics but also of clinical practice; of class struggle but also of subjectivity and desire; of the state, the party, and the union, but also of autonomy'.[874]

The idea of 'groups' also transports other connotations. Groups are important for producing signifiers and signs, including those that reference matter, content, human and non-human, or inanimate objects through language signification, and hence leading to transference. These semiotic and signifying production systems directly result from the expression of a group's politics and its state of mind. This means that groups include and produce all the signposts and reference points for unconscious thought that transfixes desire in the individual, tapping deep into the psyche through psychoanalytical transfer. Everything related to social life and non-life, the extra-personal or infra-personal, that is, between the person and the world and within the person's internal world (within their mind and through transference), is expressed through group dynamics. In fact, for Guattari, all

[873] Guattari, *Molecular revolution : psychiatry and politics*, p14.
[874] Guattari, *Molecular Revolution in Brazil*, 1, p10.

the aspects that bring about the *molecular revolution,* meaning the revolution of subjective activism, are brought about through the interaction of groups and the individual. As he suggests it:

> concerns every level synchronically: infrapersonal (at work in dreaming, creation, etc.), personal (in relations of self-domination, what psychoanalysts call the superego), and interpersonal (in the invention of new forms of sociability in domestic, romantic, and professional life, and in relations with neighbors [sic] and school)[875]

As outlined above, the effects of these expressions by groups and institutions extend to all the territories and landscapes of unconscious subjectivity that concern Guattari, either actively, remotely, or osmotically.

In the footnotes to the book *Molecular Revolution in Brazil*, Rolnik gives wider and more definitive clues to the meaning of subject-groups and subjected groups, from a purely psychoanalytical perspective:

> Subject-groups are the opposite of subjected groups. This opposition implies a micropolitical reference: the subject-group's vocation is to manage its relation to external determinations [behaviours] and its own internal law, as far as it is at all possible. The subjected group [or subjugated-group], on the other hand, tends to be manipulated by all the external determinations and to be dominated by its own internal law (superego).[876]

For Rolnik, subject groups and subjugated groups are opposites. If not, it is only to demonstrate their difference in comparison. Rolnik suggests that subject-groups are capable of managing their own destiny. In contrast, subjugated-groups are at the mercy of the subject-groups or dominant group (or leaders) who regulate laws and powers. Thus, Rolnik argues that a subject-group contains and determines its capacity to coordinate its own (legal, political, social, etc) engagements with its contexts and relationships. Therefore, the subject-group manages the subjugated group at its own discretion. This control grants a level of authority to the subject-group, particularly as Rolnik here references a potent political dimension of such a dynamic. This dimension that Rolnik calls 'a micropolitical reference' is a type of political activism that allows the subject-group to proceed on a path of self-determination and sovereignty. We can think of it as the processes that lead minorities in the process of becoming autonomous (discussed in Chapter 2). The micropolitical reference influences the emergence of a novel socio-political insurgency, given its capacity to evolve through self-analysis and articulation. The subject-group is a dynamic assemblage, especially concerning the

[875] Guattari, *Molecular Revolution in Brazil*, 1, p62-63.
[876] Guattari, *Molecular Revolution in Brazil*, 1, p471.

power it possesses to extract meaning from its context, which is central to the modification of subjectivity (and the modification of the superego).

I shall now revisit the differences between the psychoanalytical elucidations of groups discussed by Rolnik and Guattari. Let us break this down a little with an example of a therapeutic setting, such as in a psychiatric institution that contains groups. A simple instance of the subject-group as given by Guattari is '[i]n the traditional psychiatric hospital, for example, there is a dominant group consisting of directors, the financial administrator, the doctors, and their wives'.[877] The subject-group also includes nurses, cleaners and all the processes in which all those who work there participate. The process of subject-groups encompasses all aspects that determine institutional laws, types of interaction, messages, ideas, and organisational formats, through which, for instance, at La Borde, where Guattari worked, the various roles mentioned interact. Such interactions help us identify the analytical processes of the hospital's group milieu. This creates a subject-group dynamic assemblage (directors and doctors as mentioned) consisting of settings that involve the various roles people play within that context, which necessarily involve both structured and unstructured procedures, ways of doing things and ways of thinking about things.

In contrast, the subjected or subjugated-groups are the patients and their relations to their neurosis and compulsions. (The subjugated group might incidentally also include the nurses, cleaners, and all the processes in which all those who work there partake). The patients' processes of thinking and relating form a set of subjective assemblages as a collective expression of the individual, its contents and its sets of referents (the things they refer to and their signifiers). In this example, it's very plausible that a psychotic person, for example, sees themselves in a very different disordered relationship to the world than a doctor or a nurse would, simply because the process of disorder does not conform to the system of operation as the structured process of the doctor and nurse. In psychosis, the way one relates to the world is completely altered because of the illness. The patient's reference to ideas and politics in the external world, or even the institutional values that shape the patient, may not seem as well-ordered as someone from the subject group. There are always instances of imprinting values and ideas from the subject-group onto the subjugated-group due to the power differential that facilitates a transferential projection. These may be copied without being critically questioned. Remembering that transference is an encompassing phenomenon of the unconscious that often happens through osmosis (projection).

In their trip around Brazil, documented in *Molecular Revolution in Brazil*, Guattari and Rolnik articulate the struggles of subjugated-groups and offer analyses of these various groups through

[877] Guattari, *Molecular revolution : psychiatry and politics*, p16.

interviews and conversations with them.[878] These include groups such as minorities, black groups, indigenous groups, homosexuals and women's groups, as well as many of the institutional groups that are interconnected with their struggles. From these discussions (documented throughout the book), Guattari advises on the plausible ways he sees the rise of individual subjectivity at the intersection of groups and institutions. His analysis of groups encourages activism in the struggles of individuals and minoritarian groups who wish to become the determinants of their own destinies.[879] This independence is achieved by modifying their process and conducting a critical and meaningful referential analysis (process of singularization). This is an instance of what Guattari calls a 'molecular revolution',[880] the call to awaken subjectivity to find its cause and purpose for self-reformation and self-determination towards autonomy (the ideas of molecular revolution, autonomy, alternatives, and the process of singularization were discussed in Chapter 2). This push is a form of resistance in activist groups that represents the individual turn in subjectivity, marking the molecular revolution of each individual's attempt to break free from enslavement to dominant norms. Guattari suggests that through this type of invigorated subjectivity, the individual and the group can work towards:

> challenging the system of political representation, questioning daily life, and reactions that refuse work in its current form, are viruses contaminating the social body in its relation with consumption, production, leisure, communications media, culture, and so on. They are molecular relations creating mutations in the conscious and unconscious subjectivity of individuals and social groups.[881]

Guattari says the emergence of transversality is typically the vocation of subject-groups in particular.[882] Based on my analysis of transference (discussed in Chapter 4A), I would add that this also helps groups break away from their habits and disavow the servitude to the portrayal of the transferential reference that models traditional forms of analysis, which emphasise the dynamics of groups. By this, I mean breaking free from the familial projections of standard roles learnt in childhood. Guattari suggests that subject-groups possess the capacity to undertake transversal analysis and exert influence through their articulations, which express their self-determination through resistance to imposed ideas. The ability of subject-groups in transversality involves summoning relations outwardly and connecting with others' struggles both on a conscious and unconscious level. This compelling call to comprehend the interests of others, rather than getting caught up in transferential signifiers that uphold the status quo of narcissistic[883], logocentric[884]

[878] Guattari, *Molecular Revolution in Brazil*, 1, p427-46.
[879] Guattari, *Molecular Revolution in Brazil*, 1, p101-79.
[880] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[881] Guattari, *Molecular Revolution in Brazil*, 1, p63.
[882] Guattari, *Molecular revolution : psychiatry and politics*, p14.
[883] Guattari, *Molecular Revolution in Brazil*, 1, p373.
[884] Guattari, *Molecular Revolution in Brazil*, 1, p33.

discourse, is salvaged in transversality. Guattari explains this in the following passage from his essay on transversality:

> The subject group […] can produce its own tools of elucidation. Schotte could say of this type of group that it hears and is heard, and that it can therefore work out its own system of hierarchising structures and so become open to a world beyond its own immediate interests. The dependent group [subjugated-group] is not capable of getting things into this sort of perspective; the way it hierarchises structures is subject to its adaptation to other groups. One can say of the subject group that it makes a statement—whereas of the dependent group only that "its cause is heard", but no one knows where or by whom, or when.[885]

For Guattari, this idea translates into a more multifaceted complexion of transversality in groups. He sees opportunities to open up towards one another and make sense and meaning from the nonsense that can capture subjectivities[886] 'giving individuals a real hope of using the group as a mirror'.[887] 'When that happens, the individual will manifest both the group and himself.'[888] In explaining the role of transversality in groups, Guattari turns his ire on Freud's ideas on transference (outlined in Chapter 2). According to Guattari, Freud says neuroses are a 'dislocation of fundamental instincts' that requires the analyst to 'reintegrate' those tendencies, such as when dealing with 'sado-masochism'[889]—noting that transference predicates all therapeutics on neurosis. And the structure of traditional therapeutic institutions is set up to reflect what Guattari calls '"imaginary incarnation" of some of the signifying articulations of the group'[890] found in transference. We can assume that, for Guattari, these systems only amplify the neurotic articulations due to a lack of comprehension and appreciation for the full picture of the subject in question. Thus, the analyst is unable to reintegrate the patient's dislocated instinct if they cannot see the patient within the context of all their dislocations (which is the case in transference). Interpretation is fixated on a limited set of contextual references that Guattari calls a 'treasure-trove of [Freudian] signifiers'.[891] Thus, these analysts who examine the so-called neurotic transferential phenomena often fail to grasp the individual through transferential interpretation due to their limited understanding of the situation and equally limited capacity to respond. Guattari suggests that the tools needed for the analyst to reintegrate the neurotic tendencies are found in the dynamics of the process, which are more transversal, making connections to wider issues at stake for the neurotic patient. He gives a

[885] Guattari, *Molecular revolution : psychiatry and politics*, p14.
[886] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p76-79.
[887] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p116.
[888] Guattari, *Molecular revolution : psychiatry and politics*, p20.
[889] Guattari, *Molecular revolution : psychiatry and politics*, p15.
[890] Guattari, *Molecular revolution : psychiatry and politics*, p15.
[891] Guattari, *Molecular Revolution in Brazil*, 1, p394.

subtle but complex example: Suppose an institution like La Borde clinique is set up in a way that conveys 'symbolic mediation tending by their very nature to be broken down into some kind of meaning'.[892] In that case, finding those meanings may resolve the patient's problems in neurotic representations and thus reintegrate the fundamental, dislocated instincts and their related problems within the context of the issues that are problematic in the wider world.[893] By breaking down the hierarchies and examining interactions within the institution, a real-world problem may emerge that the analyst can address.

However, in more structured traditional institutions, there are systems of stratification and organisational models that are over-imprinted by 'group phantasy'.[894] Group fantasies are unrealistic or superficial ideas about the hierarchisation and glorification of roles, mission aims, and meaningless, disingenuous institutional values. Therefore, group fantasy can sometimes hijack the group's enunciations (voices, ideas, values, thoughts) and become a dead end because they return to the same structural problems that are embedded in those more structured institutions (those wrapped up in the superficialities of position and prestige). Because of these fantasies, they become 'insoluble problems'.[895] Such fantasies contain 'manifest content' (cursory ideas) that override 'latent content' (true yearning), which expresses the genuine desires of the group.[896] Simply put, group fantasies are infantilising because of this disruption and masking of the intensities of subjectivity that remain suppressed under the dominance of hegemonies and their fantasies. And those fantasies can be absorbed by the nonsense of individual fantasies that lead to further neurosis. Guattari gives us examples in structures of institutions like hospitals where the role of the medical director or the benevolent doctors, even the idea of churches, priests and their gods, all disseminate the signifiers that overlay onto such group's 'phantasies' on the pretext of organisation, efficiency, prestige'[897] and the holy spirit. Accordingly, Guattari suggests that this hinders any possibility of change if the group is returned to the same insoluble problems.[898] When there is no effective way to exchange discourse and express latent desires (true yearning), the groups resort to referencing terms from other subject-groups, thereby oscillating into the subjugated group and falling under the control of these subject-groups. In this situation, the subjectivity of its members remains in the black hole of neuroticism.[899] In such a situation, the organisation cannot find meaning because there is no

[892] Guattari, *Molecular Revolution in Brazil*, 1, p15.
[893] Guattari, *Molecular revolution : psychiatry and politics*, p15.
[894] Guattari, *Molecular revolution : psychiatry and politics*, p15.
[895] Guattari, *Molecular revolution : psychiatry and politics*, p15.
[896] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p108.
[897] Guattari, *Molecular revolution : psychiatry and politics*, p15.
[898] Guattari, *Molecular revolution : psychiatry and politics*, p15.
[899] Guattari, *Molecular revolution : psychiatry and politics*, p15-16.

mediating system of exchange between the patient and staff, clergy and the supplicant; therefore, all hope of transversality is lost. For Guattari:

> [t]ansference and interpretation represent a symbolic mode of intervention, but we must remember that they are not something done by an individual or group that adopts the role of "analyst" for the purpose. The interpretation may well be given by the idiot of the ward if he is able to make his voice heard at the right time, the time when a particular signifier becomes active at the level of the structure as a whole, for instance in organizing a game of hop-scotch.[900]

Transversality aims to resolve the disorientation and alienation when the subject-group falls into subjugation mode, initiating the subject-group to self-analyse and find meaning in the roles and responsibilities of the group or institution through the processes of self-analysis and breaking down the meaning of their messages and enunciations. However, as Guattari warns us, this exercise should not be subject to 'mouthing clichés' about its 'terms of reference,' but rather to finding and opening up points of creative expression that reference the group's latent desires at the 'level from which the group's potential creativity springs.'[901] The term 'institutional psychotherapy'[902] came to stand for this capacity of transversality to see beyond the clinical subject and encompass the very institutions of psychiatry and psychoanalysis. Guattari suggests that transversal analysis involving subjects and groups is not an attempt at 'group-engineering' but a faithful extraction of the means of expression.[903] Guattari suggests a plausible way to break down the concept is through 'group analysis in both more and less than role-adaption, transmitting information'.[904] The transmission of information gathered is usually done before norms set in, and before all possible subjective creativity is drowned out by infantilising platitudes and fantasies. Guattari advocates that information arrives through transversality and its transmission via analysis within the group, breaking the 'totems and taboo[s]' found in signifiers erected by speech that is not dealt with in normal circumstances (and, by implication, transference).[905]

This concept of transmission will become a recurring theme when discussing SRFs in the next section. It is thus important to remember how transmission invokes various modalities in thought and action. In groups, it is worth noting that signifiers crystallise in structures, solidifying roles and responsibilities and making the flexibility and responsiveness needed for change almost impossible. These crystallised structures are sometimes overlaid with group fantasy, as discussed, which shifts

[900] Guattari, *Molecular revolution : psychiatry and politics*, p17.
[901] Guattari, *Molecular revolution : psychiatry and politics*, p16.
[902] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p19.
[903] Guattari, *Molecular revolution : psychiatry and politics*, p16.
[904] Guattari, *Molecular revolution : psychiatry and politics*, p16.
[905] Guattari, *Molecular revolution : psychiatry and politics*, p16.

the breakdown of subject-groups into subjugated-groups in the examples already given. However, we view the Guattarian groups —subject-group and subjugated-group —as entities situated along a spectrum, depending on their level of transversality, which can even oscillate depending on how accurately the groups adhere to their understanding of their destiny.[906] The ability to arrive at flourishing subjectivities through transversal analysis is achieved by identifying impasses that cannot be deciphered in transference; instead, transversality and schizoanalysis are employed to diversify the analysis. The analysis of groups and institutions is nurtured through symbolic mediations and their understanding of the transmission of unconscious latent desires. This aligns with engagement in exercises that foster transversality in open societies, continually transitioning towards progress through connectivity and understanding.

In summary, to use Guattari's own words:

> What characterizes a process of singularization (which, at one time, I called the "experience of a subject-group") is that it is self-modeling. In other words, it captures the elements of the situation, it constructs its own types of practical and theoretical references, without remaining dependent in relation to global power, whether in terms of economy, knowledge, technology, or segregation and prestige that are disseminated. Once groups acquire this freedom to live their processes, they acquire an ability to read their own situation and what is taking place around them. It is this ability that will give them at least some possibility of creation and make it possible to preserve this very important character of autonomy.[907]

In due course, Guattari refers to the outcome of the subject-group processes as those that bring about 'singularization […] that is self-modeling.'[908] Guattari's singularization is the production of a subject that is inimitable in its production and assemblages, uniquely connected and constructed from its experiences. And the transition, according to Guattari, is made in the processes of group analysis and helps bring about change even when all that is involved is 'the possibility that an individual would join the group as both listener and speaker, and thus gain access to the group's inwardness and interpret[s] it' in self-reflection through transversality.[909]

[906] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p79.
[907] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[908] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[909] Guattari, *Molecular revolution : psychiatry and politics*, p20.

Transmission in SRFs

The term transmission is taken and used without contestation in the field of science. In the field of SRFs, transmission refers to the transfer of mechanical forces, the transmission of electronic signals that guide or control the SRFs, and the electronic transmission of power to actuators or to drive motors of the SRF. The terms appear to have the same universal illocutionary meaning across various related fields of engineering, such as the transfer of energy, electricity, or electrons.

The Oxford English Dictionary defines transmission as '[t]he action of transmitting or fact of being transmitted; conveyance from one person or place to another; transference.'[910] *Trans* is a prefix meaning 'to go through, to cross,' and its Latin derivations even take us to words like 'traducere,' which means to lead or convey across[911]. My favourite etymological moment is the word's progression to the Latin '*tansformare*', which is to change in shape.[912] The variation to *tra*, even takes us into the Latin *intrate* or to enter.[913] 'Trans' for transmission is found to be used liberally in electronics, in words such as transducer, transponder, and transceiver, as well as in chemistry and especially in related fields of medicine and biomedical technology. Geographically, it is effective in denoting the spatial coordinates of international locations and borders, as seen in terms such as transatlantic and transnational. Additionally, it is used in more modern contexts to reference sexual identities, including transgender, transsexual, transman, transwoman, and (unfortunately) transphobia.[914] Joaquín Villalba's paper on the 'Origin, history, and meanings of the word transmission'[915] suggests that '[t]he origin of the words to *transmit* and *transmission* and their derivatives can be traced to the Latin *transmittere*.'[916] This, in turn, clarifies our understanding of the prefix *trans* meaning 'carry across or beyond', in relation to the verb *mittere*, which is to let go or send.[917] In its current form, says Villalba, typified in the late twenty-first century, it has come to be used in increasing 'dynamic disciplines' such as 'scientific and technical jargon' that fills linguistics of 'modern natural science, including genomics,

[910] "OED : Oxford English dictionary : the definitive record of English language," in *Oxford English dictionary* (Oxford: Oxford University Press). https://www.oed.com/dictionary/architect_n?tab=meaning_and_use#39979088.
[911] Joaquín Villalba, Fernando A. Navarro, and Francisco Cortés, "Origin, history, and meanings of the word transmission," *Microbiology spectrum* 5, no. 6 (2017): p2, https://doi.org/10.1128/microbiolspec.MTBP-0004-2016.
[912] Villalba, Navarro, and Cortés, "Origin, history, and meanings of the word transmission," p2.
[913] Villalba, Navarro, and Cortés, "Origin, history, and meanings of the word transmission," p2.
[914] Villalba, Navarro, and Cortés, "Origin, history, and meanings of the word transmission," p5.
[915] Villalba, Navarro, and Cortés, "Origin, history, and meanings of the word transmission."
[916] Villalba, Navarro, and Cortés, "Origin, history, and meanings of the word transmission," p1.
[917] Villalba, Navarro, and Cortés, "Origin, history, and meanings of the word transmission," p1.

molecular microbiology, hospital epidemiology, molecular genetics, biotechnology, evolutionary biology, and systems biology.'[918]

In the field of SRF transmission, although it is frequently referenced in journal articles, it is not always explicitly mentioned; instead, it is often inferred when discussing the conveyance of power, signals, and mechanical forces. This tendency is very noticeable in publications on Robotics, Engineering, Biotechnology, Mechatronics, and Electrical Engineering, to name a few I have cited (explored in Chapter 3). A typical remark would be when Leigh et al. discuss the transmission of EMG signals from the muscle to the SRF interface, where they refer to '[t]he raw EMG signal from the muscle'.[919] The locution is also often inferred when speaking of the actuation of motor systems, the output of which is also associated with the transmission of generated forces on the body by the SRF when grasping an object. For example, Hussain and Pattrichizzo suggest, '[t]he transmission solutions allow motion of other joints'[920] when speaking of how an SRF adapts to an object after it has made contact with it and been affected by a force in that contact event. Ipso facto, the input of mechanical forces, such as those just referenced, is also transmitted through power transmission to the '[t]he module actuators controlled servomotors'[921] that mechanically move gears and pulley systems to change the level of actuation, that is, to slow or fasten the motor responses.

In the literature on SRF, there are many references to the words actuation and underactuation, as well as their alternative tenses, that are entwined with the semiotics of transmission, as just mentioned. Actuation describes the mechanical devices used in motors that drive the motion of the SRF (explored in Chapter 3). In Hussain and Prattichizzo's book *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*[922], the locutions of actuation and underactuation appear fifty-eight times and fifty-nine times, respectively. In robotics, actuation refers to a device that causes motion or movement. For example, when 'the motor actuation pulls the tendon, fingers close'.[923] Often, the actuation unit provides mechanical power, which is transmitted through 'mechanical transmission and differential mechanisms' systems with a moving pulley.[924] For

[918] Villalba, Navarro, and Cortés, "Origin, history, and meanings of the word transmission," p1.
[919] Leigh and Maes, "Short Body Integrated Programmable Joints Interface." p6056.
[920] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, p43.
[921] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, p107.
[922] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*.
[923] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p4.
[924] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p11.

instance, Malvezzi et al. explain an instance of an SRF where 'each finger is actuated with a single tendon, connected on one side to the actuation and transmission part'.[925] (seen in Figure 43).

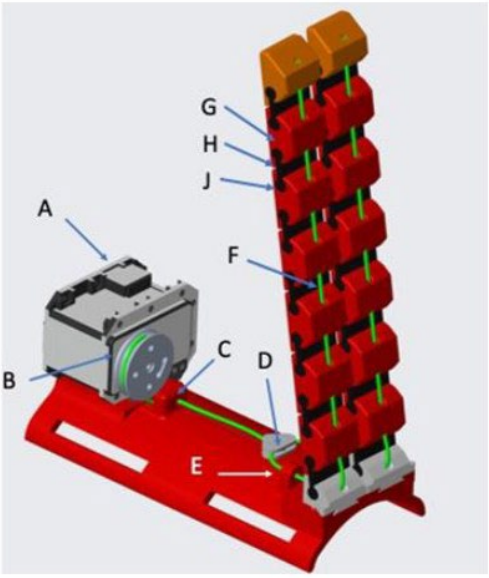

Figure 44 - SRF showing the actuator A and the transmission unit underneath that connects to B, the drive pully, taken from Malvezzi et al.[926] —main components of the device. Tendons are represented in green. A—actuator. B—drive pulley. C—A fixed pin is necessary to provide a suitable direction to the tendon. D—Sliding element. E— elements necessary to provide the right directions to finger tendons. F—Tendon. G—Rigid interphalangeal element. H—Flexible joint element. J—cylindrical connection between rigid and flexible elements.

Malvezzi et al. point out that 'transmission systems have a great importance in robotic hands', where different transmission systems exist for different design ontologies of SRFs.[927] Typically, transmission systems utilise a system of two or more gears to control the mechanical power (torque) or power ratio. Malvezzi et al. suggest that 'a differential system based on gears is used for a novel architecture of robotic hand and the properties of differential mechanisms arranged in cascade via parallel or serial connections'. [928] Hussain and Prattichizzo propose that 'transmission solutions allow motion' of joints to take place in the SRF[929]. However, there are other facets of the illocution of term transmission, bringing into operation the main definition related to the transmission of electronic signals or power.

[925] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p4.
[926] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p5 Figure 3.
[927] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p1.
[928] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p2.
[929] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, p43.

The locutionary term of transmission is also part of the 'somatosensory feedback'[930] information loop that is vital for grasp capability in determining when and how hard it is to grasp or touch objects.[931] It gives the human grip the signal to know when to hold and let go. There are also various illocutionary meanings associated with the term transmission signals, which are intended to convey a method for conducting signals that successfully control and interface with an SRF system. The bi-directional transmission system, part of this electronic ecosystem, provides a feedback loop to the sensory system. This loop enables a neural reaction to transmit a signal back to the SRF or third-thumb, which is crucial for achieving a timely response and fostering a sense of embodiment.[932,933] Without it, the hand will find it hard to promptly coordinate a synchronous response of the SRF with the movement of other fingers.

These systems of transmission that operate an SRF can be interfaced with intermediary systems such as synergetic[934] and bio-artificial mapping[935], as discussed in Chapter 3. The intelligent algorithmic structure of synergetic and bio-artificial mapping predicts the SRF's movement in line with the hand's movement, based on past data collected from the movements of other fingers and the hand. At other times, transmission signals are captured or intercepted directly from the neuromuscular junctions of the body's nervous system and used to control the SRF in cases where a limb is missing. These bodily systems use signals from various locations. The systems utilise innervation signals (transmitted) directly from the body, including the frontalis[936] or eyebrow area, the auricular vestigial muscle[937] that moves the ear, eye movements,[938] and also from various residuum sites connected to the termination point at the amputation. The interconnection of the body and the technology of these instances is known as body-mediated systems. It is an example of what transversal (transversality) systems would envisage in the 'bio-digital'[939] age of convergence. The signals captured can transmit information to the systems that interface with the SRF, together with those mentioned above and are vital for a successful embodiment of the SRF or third-thumb. An

[930] Shikida, Noel, and Hasegawa, "Somatosensory feedback improves operability of extra robotic thumb controlled by vestigial muscles," p1.
[931] Hussain et al., "A soft robotic supernumerary finger and a wearable cutaneous finger interface to compensate the missing grasping capabilities in chronic stroke patients," p188.
[932] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p940.
[933] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p267.
[934] Leigh and Maes, "Short Body Integrated Programmable Joints Interface." p6053.
[935] Wu and Asada, "Bio-Artificial Synergies for Grasp Posture Control of Supernumerary Robotic Fingers."
[936] Hussain et al., "The Soft-SixthFinger: a Wearable EMG Controlled Robotic Extra-Finger for Grasp Compensation in Chronic Stroke Patients," p1001.
[937] Meraz, Shikida, and Hasegawa, "Auricularis muscles based control interface for robotic extra thumb," p3.
[938] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p261.
[939] Michael A. Peters and Petar Jandrić, "Posthumanism, open ontologies and bio-digital becoming: Response to Luciano Floridi's Onlife Manifesto," *Educational philosophy and theory* 51, no. 10 (2019): p971,73, https://doi.org/10.1080/00131857.2018.1551835.

example of a more manual system discussed in Chapter 3 is a system that uses a manual switch on the finger[940] called a hRing. The integration of such systems helps the body and mind feel more unified with the rest of the body schema.[941] Thus, the timely transmission of signals between body parts and the brain (biological and machinic) helps ensure the seamless operation and integration of the SRR or third-thumb.

Lastly, the interfaces mediating transmission signals can also include other cognition and perception systems. The transmission systems in these processes involve integrating neurogenerative signals directly to and from the brain, bypassing the body altogether, as found in BMI interfaces or using EMG signals from the head, such as the eCap technology reviewed in Chapter 3.[942] To remind us, Hussain et al.'s paper on the Soft-Sixth Finger refers to using the 'eCap, a wearable wireless EMG interface where electrodes, acquisition and signal conditioning boards are embedded in a cap' to help control the SRF.[943] The eCap transmits the signals from the user's head to the SRF, where 'acquired EMG data are transmitted wirelessly to the actuator's controller'.[944] Here, transmission is used to transfer electrons more commonly for signaling via Bluetooth, and as Malvezzi et al. describe it in their illocution of transmission, it is understood as a means of 'electro-mechanic transmissions'.[945]

More advanced researchers are endeavouring to use a strategy to integrate all transmission signals from various locations of the body, thereby providing more prompt responses to the SRF.[946] Transmission may be mediated by emerging systems that map the fingers' behaviour to that hand using artificial intelligence (AI) systems that predict the movement of the hands and fingers' intentionality.[947] Some of these systems use system signals to transmit movement readings from the natural functioning of other hands or other parts of the anatomy. This may include using the fingers of the opposing hand and employing a specialised glove that reads and mimics its movement using bioartificial and synergistic mapping information, which tells the SRF how to act when hand or finger motions are made.[948]

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[940] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p16.
[941] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p636.
[942] Hussain et al., "The Soft-SixthFinger: a Wearable EMG Controlled Robotic Extra-Finger for Grasp Compensation in Chronic Stroke Patients."
[943] Hussain et al., "A soft supernumerary robotic finger and mobile arm support for grasping compensation and hemiparetic upper limb rehabilitation," p5.
[944] Hussain et al., "A soft supernumerary robotic finger and mobile arm support for grasping compensation and hemiparetic upper limb rehabilitation," p6.
[945] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p1.
[946] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p940.
[947] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," 942.
[948] Ort et al., *Supernumerary Robotic Fingers as a Therapeutic Device for Hemiparetic Patients*.

Not all systems have to be so complex. Let us also consider Danielle Clodes and Tamar Makin's Third Thumb. Danielle Clodes's Third Thumb design, as used by Makin et al., included manual systems that utilised the toes to control the abduction and adduction of the thumb.[949] These physical particularities of transmission involve the use of cumbersome wires to control the movement of electrons, currents, and voltages in transmitting signals that connect Clodes Third Thumb to the toes, serving as a mechanism of control (discussed in Chapter 3). Makin et al. advise that the '[t]he motors are mounted on a wrist strap and powered by an external battery pack worn on the upper arm.[…and] The pressure sensors are powered by external batteries secured around the ankle'[950]. This takes the load off the wearer's arm, reducing mechanical forces and increasing comfort. However, it requires a wire to traverse the length of the body to transmit the power to the finger. Returning to other types of SRFs, Prattichizzo et al. summarise the drawbacks and advantages of 'fully actuated SRF configurations as being very precise and reach a variety of configurations but require a higher number of motors, sensors, and batteries, which can hinder the wearability of the device.' [951] in contrast, Hussain et al.'s Double Sixth Finger, which only uses a single actuator, seems to be the gold standard for comfort because it reduces the burden of weight. It also reduced the number of wires and motors needed, thus reducing the need for power transmission to various actuators. The Double Sixth Finger controller and battery actuator are on the user's belt. Like Daniele Clodes's Third Thumb, it positions the battery away from the arm in a more ergonomic position. However, the disadvantages are that it also requires a longer length of wiring to reach the power source of the SRF and can be entangled with the body during vigorous movement. These are just a few examples of the many SRFs reviewed, demonstrating the conundrums of using wires for various transmission systems.

As discussed earlier, the elocutionary use of the term transmission is evoked when speaking of the transmission of forces used in the animation of the SRFs. The transmission of forces between the SRF and the user's hand or arm doesn't always include the architecture of a 'traditional inelastic element joint drive [motor] system'.[952] Not all SRF architecture is made of hard materials such as metal and rigid plastics. Some researchers have innovated using resounding foresight, developing pneumatic and fluid systems or soft actuators – motors that are 'novel hydraulic systems that simulate joint flexibility'[953] that absorb some of these transmission forces between the SRF and the user. I refer to

[949] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p2.
[950] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p2.
[951] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives," p3.
[952] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p938.
[953] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p942.

a completely radical design vis-à-vis the research by Singh et al., a 'fully pneumatic fibre-reinforced soft bidirectional bending actuator (SBBA) made up of soft pneumatic rotary actuator (SPRA).'[954] Other examples include the advent of a 'hybrid (tendon-driven and pneumatic)'[955] system by Gerez et al. The added benefit of such a simple innovation, such as soft actuators and soft motors, is that it avoids the need for the accompanying pulley systems that are so awkward and unwieldy for the wearer. Soft pneumatic motors enhance safety and grasp compliance, improve weight-to-load ratios, and make users more comfortable because they flex and conform to the body more easily, as explained by reviewers Tong et al.[956] There are other advantages to the soft SRF ontological structure of the soft/pneumatic actuator architectures just described - the transmission of 'power is more natural, which can provide parallel tension with human muscles or tendons'.[957] Because it lacks the numerous motors of fully actuated SRFs, it appears less machinic and more anthropomorphic, lacking the wires and mechanical Dickensian architectures that are aesthetically unpleasing. An example of the more pleasing pneumatic-driven SRF is seen in Figure 44. According to Tong et al., '[i]n terms of social and psychological aspects, soft SRLs are less noticeable, reducing the wearer's psychological burden.'[958] Thus, by employing innovative thinking, altering the transmission systems modulates the architecture of the SRF's design idea to enhance the level of acceptability and comfort for the user.

[954] Singh and Thondiyath, "Design and Analysis of a Soft Bidirectional Bending Actuator for Human-Robot Interaction Applications," p2.
[955] Gerez et al., "A Hybrid, Wearable Exoskeleton Glove Equipped With Variable Stiffness Joints, Abduction Capabilities, and a Telescopic Thumb," p173345.
[956] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs."
[957] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p934.
[958] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs," p934.

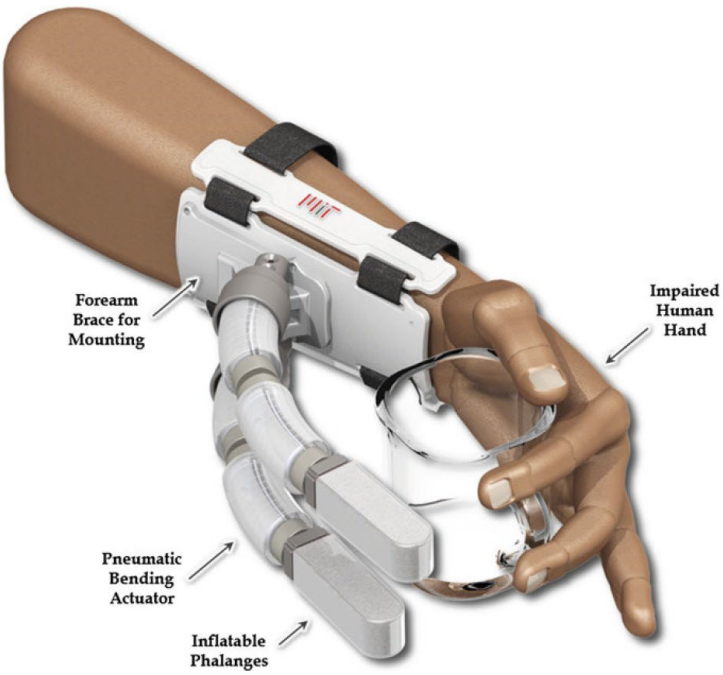

Figure 45 - Pneumatic supernumerary robotic fingers being used to provide grasp assistance to individuals suffering from stroke-induced hand impairment. An example of a soft pneumatic SRF was taken from Hammond III et al.[959]

We can consider that the varied concepts of transmission uncovered in the discourse on SRFs, implicit and explicit, greatly affect the performance of the SRF. The systems thus far discussed use the term transmission to denote 'to transmit motion and power',[960] signals, and mechanical forces, which ultimately determine the usability of the SRF. These determine the design ontologies that influence the ergonomics, psychological, and social visual values, as well as acceptability, wearability, and human-machinic integration issues in the architecture of SRFs, which have posed challenges to user acceptance.

Group transversality and transmission

The concept of transmission in SRFs can be (re)considered through the analysis of the transversality of group analytic processes when thinking of subjectivity. Semiotics, in Guattarian terms, has one foot in the postmodern understanding of signs in which language is just one component, and another foot in the complex ideas of Charles Sanders Peirce and Louis Hjelmslev. For immediate purposes, Guattarian semiotics, can be thought of as a stand-alone social system of understanding

[959] Hammond Iii, Wu, and Asada, "Variable Stiffness Pneumatic Structures for Wearable Supernumerary Robotic Devices," p203 Figure 1.
[960] Hussain et al., "An EMG interface for the control of motion and compliance of a supernumerary robotic finger," p3.

signs, especially the abstract ideas they convey. As we keep this in mind, we must also acknowledge that it would be very hard for any analysis to preclude the transmission of knowledge that undergirds all technological developments in the field of SRFs and, for that matter, throughout society, without examining its semiotics. The analysis of the transmission of knowledge operates within the same domain as the process of transferential phenomena, as both involve the transfer of messages and the transfer of information from one person to another. Having situated transference (discussed in Chapter 4A) and transmission within the same domain, as a movement from *a* to *b*, we might analyse how the two terms contain an illocutionary function that contains what I argue is an elemental capacity for theoretical discussion via Guattarian transversality. From prior explanations of transversality, the proposition put forward in relation to transmission in the field of SRF has touchpoints that extend beyond improving ontological design, having much more far-reaching effects. The consequences of transmission shall be examined in relation to SRFs as an illocutionary concept with equally potent theoretical significance. That is a *speech act* that is performed. These comparisons and analyses have a bearing on everyday life and the socio-political characteristics that produce Guattarian subjectivity.

Let's take a moment to distinguish the difference between semiotics and semiology (continuing from Chapter 4B) because, for Guattari, a distinction has a material effect on the concept of transversality. Semiosis is the direct relationship between the sign and the signifier, an 'intralinguistic'[961] relationship (the relationship between words and their signs) predominantly associated with the structuralist Ferdinand de Saussure. At nearly the same time, Charles Sanders Peirce distinguished his ideas on how we interpret the world building on Saussure's work but distinguishing his work to include the very other interjecting vectors of interpretation and understanding of sign (the intersubjective meaning) that enable us to read signs that included the experiences such as 'all sensory stimuli that could create another idea in the receiver's mind'.[962] The extent to which these two competing ideas have dominated the field of linguistics and philosophy will not be explored here. However, it is worth noting that, as a semiotician, Guattari prefers to use semiotics due to its post-structural intensity, which includes the environment or context to which an object is subject and its referent.[963] This also includes the subject's mental notion of that object in the propositions of communication, which includes all the senses and sensibilities of subjectivation (the process by which the subject is constructed through the referents).

[961] Russell Daylight, "The difference between semiotics and semiology," *Gramma Journal of Theory and Criticism* 20 (2014): p1, https://researchoutput.csu.edu.au/en/publications/the-difference-between-semiotics-and-semiology.
[962] Daylight, "The difference between semiotics and semiology," p1.
[963] Guattari, *Molecular Revolution in Brazil*, 1, p339.

In keeping with Guattari's semiotic analysis, we can perceive the morpheme *trans* as capturing more than one meaning and expanding to more than one existential territory of the referent. The morpheme *trans* also carries the hope that a way of thinking built into transversality can give way to its operations in the transmission of intra- and inter-group dynamics, as well as in describing the transfer of diverse and interconnected thinking between them. Through this analysis, we can infer the connections between the two verbs, transmission and transversality, and their application in this context. This is important because, as Guattari suggests, the use of language signposts the view of the world, projecting upon and being swept up by our psyche. Subjectivity has its roots in the significance and application of pragmatics, which contribute to the creation of the individual's sense of self.[964]

The prefix *trans* links the words transference, transversality, and transmission, as well as being used in more words such as transhumance and in modern terms to reference sexual identities, such as transgender, transman, transwoman and (dare one say) transphobia.[965] However, it is interesting to note that this analysis of transmission, which incorporates concepts of transversality between groups and Guattarian thoughts, reveals a diagrammatic interaction (as opposed to semiotic redundancy) between the two verbs, thereby strengthening the connections between them. Rolnik defines semiological redundancies in this way: 'semiological redundancies only represent, providing "equivalents" of realities, without any operational impact.'[966] This is opposed to diagrammatic interactions, where 'diagrammatic interactions make sign systems work directly with the realities to which they refer',[967] giving us instances of diagrammatic versus semiological interactions. Rolnik gives:

> [e]xamples: mathematical algorithms, technological plans, and computer programs participate directly in the process of creating their object, whereas an advertising image can only give an extrinsic representation of its object (but then it is a producer of subjectivity).[968]

The two words transversality and transmission, as a function of groups thus carry both diagrammatic interactions in the scientific architectures of the SRF and semiological redundancy in the semiology of groups and their transmissions of information. Given that we covered the etymology of the word transmission and its examples in the field of SRF, we can thus say that word transmission becomes an equally dynamic proposition as complex as the word transversality. However, using Guattarian ideas, we know that transversality does not occur in subjectivities out of thin air, *ex nihilo*. As

[964] Guattari, *Molecular revolution : psychiatry and politics*, p143.
[965] Villalba, Navarro, and Cortés, "Origin, history, and meanings of the word transmission," p5.
[966] Guattari, *Molecular Revolution in Brazil*, 1, p471.
[967] Guattari, *Molecular Revolution in Brazil*, 1, p471.
[968] Guattari, *Molecular Revolution in Brazil*, 1, p471.

Guattari says about subjectivity, '*that the formations of the unconscious do not derive from a* déjà-là *but are constructed, produced, and invented in processes of singularization*'.[969] This means that the process of transversality in subjectivation is made/produced in the process of singularization 'which, at one time, I called the "experience of a subject-group"' [970] declares Guattari. As discussed, this is achieved through groups and institutions, which influence the dynamics of transmission of both conscious and unconscious utterances, enunciations, significations, and their byproducts in the semiotics that are outwardly projected, capturing/spreading messages and images in a scattergun-like manner. These are received and processed by the individual's superego and are part of their formation in the construction of their subjectivities. So if, for example, a psychiatrist starts telling us that people who have coffee in the morning are crazy, eventually, we either stop drinking coffee in the morning or we start thinking there is something wrong with us. We don't realise that there may be some backstory to how psychiatrists developed this idea. The anti-coffee lobby could have provided this research to the psychiatric community with sinister, economic, or political intentions. As Guattari puts it, 'this function of collective facilities that codifies conduct, behaviour, attitudes, and value systems practically by remote control.'[971] Similarly, the concept of knowledge transmission in the field of SRFs is conveyed through remote control. In our instances, the collective facilities of research groups and institutions convey their value systems, codified conduct, behaviours, enunciations, significations, and semiotics, which are constructed from habitual ways of thinking within their scientific communities. Thus, science has its own set of politics that is no less pervasive than that of societies of capture/control.

When analysing transmission systems in the field of SRF, researchers have not challenged the fundamentals of systems comprising actuators, pulleys, motors, and gears, which pose challenges to the usability and wearability of SRF. We can say that there have been transversal thoughts and ruptures in thinking, which is the exception rather than the rule, among the small group of researchers who have pursued the development of SRF by examining soft actuators and pneumatic motors, which is innovative. However, a recurring theme in most research projects tells a different story, with many challenges remaining unresolved. These challenges confound researchers because they show the same tendencies to repeat and build on old habits and ways of thinking via structured seniotics.

How can we then increase the type of transversal thinking similar to that carried out by those who are exceptions to the rule and have been innovative in thinking outside the box? How can we

[969] Guattari, *Molecular Revolution in Brazil*, 1, p310.
[970] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[971] Guattari, *Molecular Revolution in Brazil*, 1, p181.

enhance ergonomics and SRF usability to increase user acceptance? How can we better design an SRF that is more readily accepted by the body and mind in embodiment? The field of SRF faces a significant challenge in resolving issues related to the ergonomics of the weight, size, and number of actuators and motors used. Like transference, in an ever-never-ending loop, using myths and mathemes, the researchers on SRF continue to follow the same scientific thinking and pathways in epistemology, searching for solutions that elude them with a high level of repetition and failure, hoping that something will change. It can be said that the current architecture of the actuators and motors is equivalent to the limited number of signifiers that trap the patient (being the researcher) in the black hole of transference in the therapeutic setting, as Guattari has highlighted. If more researchers explore ideas in a transversal mode, such as the disruptive use of pneumatics, they might discover new pathways to building SRFs by departing from old and habitual ways of thinking. This approach could lead to the discovery of new solutions. Using this transversal move away from habitual thinking may provide a new way of building alternative solutions and interrogating the epistemology with a diverse and fresh outlook.

Intellectual explorations and the epistemological basis for the mechanical development of systems that comprise the SRF, such as those already mentioned, are often conducted by groups and institutions with publishers serving as gatekeepers. What has been considered valid and acceptable research is a type of Guattarian struggle for those who do not meet this benchmark. Here, I am referring to the struggles of subjugated groups discussed earlier in this chapter (and those discussed in Chapter 2) or the minoritarian struggle of people with polydactyly, as discussed in Chapter 4A. An individual researcher's subjective desire for research outside the mainstream ideas incorporates their unconscious dreams, aspirations, and vision for their research but finds their hopes gridlocked by those who operate the power structures within the subject groups (fantasies) that project their influence and ideas on what is valid. Here, we reach the threshold of a Guattarian level of group struggle, manifest between the subject-group and the subjugated group, where transversality has been completely shut out. It is fair to say that the level of cross-referencing among researchers in the SRF field is intense (thus the transmission of knowledge and its semiotics). Intense, but also likely restrictive. These groups that subjugate work on ideas that contain group fantasies (and include ideas of prestige discussed earlier in this chapter) that justify what is considered ideal research. There appears to be a hegemonic dominating relationship in scientific communities between those who produce orthodox research and what reviewers, other researchers and publishers consider worthy. When considering Guattari's ideas on subject-groups that subdue other groups into a subjugated status, a similar issue arises in the field of research that corresponds to the oppressive tendency described above. The coercive nature of this situation emerges when organisational

messaging from the gatekeeper transmits a type of language, signification, semiotics, a type of reference that sweeps away all transversal knowledge, dismissing anything that doesn't fit into its already pre-modelled structures of thought. In this way, groups in power who are influential interject into the processes that shape the subjectivity of others, imposing their values and interpretations upon society. This happens in the politics of dogma or societies of control. That is the mirroring of ideas and values by dominant groups without any accountability, all the while reinforcing homogeneity. In return, the groups under such control respond in countertransference (discussed in Chapter 4A) with the already anticipated responses that reify the systems, relinquishing any possibility for diversity in thought or experimentation.

The desire within research groups to produce innovative ideas brings into focus Guattarian ideas of the manifest content (cursory ideas) of the organisation or institution, which can be at loggerheads, thereby extinguishing any latent desire (true yearning). This can hinder the development of transversality and multidisciplinary insights. The tensions between such states are grounded in the systems of capture, as critiqued by Guattari.[972] Guattari's ideas of group fantasy evoke similar conditions in the SRF discourse around the politics of funding and prestige, in which wishful organisational strategies and ideals overtake any creative vision, will, and yearning to explore or experiment. Consistent with Guattari's ideas on group fantasies, scientific institutions are prime examples of institutions similar to psychoanalytical institutions that work to infantilise subjectivity, in line with discussions about groups in Guattari's explanations of how they can operate. Equally, there is a similarity between the scientific institutions that mediate scientific output, which is as inflexible as Guattari's description of institutional and psychoanalytic structures set up in psychiatric institutions, in such a way that they don't provide a holistic approach, consequently reifying neurosis. Subject-groups that occupy such hegemonic positions are the bodies that dominate the discourse and hold positions of power in which they actualise stratification and hierarchisation, resisting transversality or transformational forces. The discourse of subject-groups can exercise its power to shut down diversification and enforce structure, rather than leading to transversality, thereby returning to the peril of the encirclement of transference and castration anxiety. I relate this idea to the field of SRF, where researchers' latent desires (true yearning) to challenge scientific conventions run into 'totems and taboo[s]'[973] set up to restrain them against challenging the very fundamentals of a field of study, always guaranteeing outcomes that fit the predefined structures. This type of reification is inscribed in scientific studies and technological experimentations that work within already established discourses rather than charting new ground through experimentation,

[972] Guattari, *Molecular Revolution in Brazil*, 1, p256.
[973] Guattari, *Molecular revolution : psychiatry and politics*, p16.

even though failure is likely. In this way, the subject-groups are compromised by such spectacular failures that their fate oscillates between their current state and that of subjugated groups, marked by helplessness and brokenness through submission. When groups close in upon themselves in such a way, the transmission of information between groups, the messages that make permissible latent desires, the transversal messaging of enunciations that can make sense of the nonsense or bring relations to solutions to the problems before us, are lost. All creativity is obliterated. As Guattari says, '[a]ll creativity in the social and technological field tends to be crushed, every microvector of singular subjectivation is co-opted.'[974] Along these lines, researchers who wish to pursue ruptures outside the mainstay and conduct less orthodox research are discouraged and risk slipping into subjugated groups, which develop a reactive sense of neurosis within their professions. The alternative offered here is that transversality permits, as Guattari describes, for desire to be expressed in subjectivity, where the 'data received by the super-ego is modified, and, consequently, the threshold of the castration complex [increased], specific to a given social order, can be locally modified'[975], freeing researchers to act upon their intuitions. Guattari points out that the opposite happens in oppressed groups, such as in the groups that are forced to conform, whereby the superego is controlled by 'remote control.'[976]

The need for better transmission systems is the primary problem facing the design of a third-thumb, which necessarily requires foresight in transversal creations that draw on multi- and interdisciplinary insights. This problem of bulky motors and actuators may require solutions such as miniaturisation and more efficient and discreet systems of power conduction that aren't based on the archaic system we currently use. When determining how to bypass wire transmission of power from the batteries to the SRF and how to convey control signals from the body to the SRF without wires (similar to Wi-Fi signals), a significant amount of abstract and creative thinking is required. If we have thought of a way to recharge our batteries wirelessly, surely there will be a time when the challenges that face the physics of these transmission issues can be overcome. It may require stepping back and reexamining how the physics of transmission needs to work, such as by utilising quantum mechanics, nano-electronics, or new materiality. Such cross-pollination of movements between disciplines may lead to increased complexity, but it can also provide connections between, for example, classical physics and quantum physics. Guattari suggests that in transversality, there is:

[974] Guattari, *Molecular Revolution in Brazil*, 1, p54.
[975] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p79.
[976] Guattari, *Molecular Revolution in Brazil*, 1, p181.

> a way of rejecting all these modes of preestablished encoding, all these modes of manipulation and remote control, rejecting them in order to construct modes of sensibility, modes of relation with the other, modes of production, modes of creativity that produce a singular subjectivity.[977]

It is impossible to predict the modes of sensibility, the modes of relation, and the modes of production that will lead to innovation in finding better ways to transmit power. We may have already seen an example of that approach, which has led to research on SRFs exploring the possibility of using soft and pneumatic motors to operate a third-thumb. It is not impossible to imagine finding better ways for users to experience the third-thumb without the burden of a large battery pack and wires hindering their movements. For such a groundbreaking change to occur, Guattari would challenge the prevailing habits of thought. In the following passage, Guattari critiques the entrenched types of thinking prevalent across all institutions, including even the progressive spaces of universities. Guattari criticises the reactionary ways in which these groups (academics) respond to defend the status quo and resist innovation. His reference in the passage below considers his observations of such situations. We can correlate Guattari's ideas with the fields of epistemology, science, engineering, and robotics in the context of SRFs. Guattari proposes that:

> [p]eople in therapeutic systems, or in the universities, who consider themselves to be mere depositories or channels for the transmission of scientific knowledge, have already made a reactionary choice. Despite their innocence or goodwill, they really occupy a position that reinforces the systems of production of the dominant subjectivity.[978]

Guattari then points to the tragedy of subjectivity trapped by the capture of structures of control that adulterate our universities and 'channels for the transmission of scientific knowledge'. Putting into perspective Guattari's thoughts on this issue of transmission of scientific knowledge, we must temper his claims with his other views regarding science as a force that can equally work in revolutionary ways, breaking away 'from oppressive hierarchies—nonarborescent, "rhizomatic," "transversalist" models'[979] if the right level freedom and autonomy prevails (i.e. found in transversality).

Guattari's insights into subjectivity are derived from his analytical schematics that animate the understanding of group struggle. He says, 'the affirmation of the processes of autonomy and the existence of great machines for struggle' is the basis of subjective beginnings.[980] The great machines Guattari refers to in this passage come from a passage in his discourse with his Brazilian interlocutor

[977] Guattari, *Molecular Revolution in Brazil*, 1, p23.
[978] Guattari, *Molecular Revolution in Brazil*, 1, p41.
[979] Guattari, *Molecular Revolution in Brazil*, 1, p274.
[980] Guattari, *Molecular Revolution in Brazil*, 1, p210.

during his tour of Brazil. During his travels, Guattari references the struggle of the members of the Workers Party, called PT, to help them bring together the voices of its minorities, workers, Brazils disparate indigenous tribes, women, homosexuals and other diverse sections of society into the political fray during a tumultuous period in Brazilian history when people were 'overthrowing the dictatorship'[981] and trying to establish democracy[982]. We can equally apply these ideas to the scientific endeavours of researchers who wish to bring about change in their struggle to be free from the domination of academic conventions. Guattari encourages individual subjectivities to rise to the occasion by using analytical (schizoanalytic) group processes (levels of understanding of latent desire) to reach for transversal territories using the 'instruments of struggle, [with] new types of conceptual references to understand the evolution of these unaccustomed situations.'[983] These 'unaccustomed situations' to which Guattari refers are the opening up of hope in the struggles against habitual situations we confront in everyday life. Guattari attempts to revitalise activism in subjectivity, allowing people to connect to their inherent will to seek autonomy. Activism in subjectivity is the presuppositions enacted during resistance and recruits the types of alliances formed during transversality. Resistance highlights the various approaches to addressing the challenges confronting the science of SRFs. The resistance to which Guattari refers is the resistance for 'autonomy of subjectivity through group struggles and activism[984]. This deployment of activism through subjectivity is important for its 'micropolitical reference' to the small yet significant collective polity of subject-groups to which Rolnik refers.[985] Guattari's groups are like machines, and their need to connect is ingrained in their production of subjectivity. According to Guattari, to break free from the transmission of tyrannical relationships that modulate the oscillations between subject-groups and subjugated groups, groups must constantly work at mediating symbolic meaning through the analysis of semiotics and the roles played by individuals and their institutional fantasies, thereby returning to the existential territories of transversality. Guattari urges groups to refer to therapeutic analytical processes that help mediate the function of meaning from semiotic cues, capturing the many intersections of the polity of context, the environment and its interaction with the subject's psyche. Thus, the groups and organisations must dispel the useless orthodoxies and structural frameworks that serve no function. My examination of Guattari's analysis of the analytical process of groups may provide grounds for reassessing the values that determine their worthiness in substantiating the realities of the context in which they are situated. In the field of SRF, this means

[981] Guattari, *Molecular Revolution in Brazil*, 1, p459.
[982] Guattari, *Molecular Revolution in Brazil*, 1, p416-17.
[983] Guattari, *Molecular Revolution in Brazil*, 1, p267.
[984] Guattari, *Molecular Revolution in Brazil*, 1, p62.
[985] Guattari, *Molecular Revolution in Brazil*, 1, p471.

the provisional consideration of ideas and their relationships to transversal connections in other fields of study, formulating a diverse gnoseological viewpoint.

Given our understanding of Guattari's ideas on subjectivity and resistance, those in the field of SRF would be encouraged to open themselves up to other groups and create space for change through group analytics that foster transversal connections. Guattari argues that we cannot dismiss the interweaving of subjectivity with the production of scientific knowledge, as subjectivity is inherently involved in systems of production, where capitalist production holds the upper hand in controlling all forms of production, including subjectivity.[986] Guattari warns of the profound influence of social control and the impact of capital on our conception of identity when he discusses subjectivity. He makes the following assertion, which I think is a corollary to the research in the field of SRFs. Guattari advises:

> [w]hat is produced by capitalistic subjectivity, what comes to us through the media, the family, and all the resources that surround us, is not just ideas; it is not just the transmission of meanings through signifying statements […] More essentially, it is systems of direct connection between, on the one hand, the great machines of production and social control and, on the other, psychic agencies, the way of perceiving the world.[987]

There is a direct relationship between the production of subjectivity and capitalistic production. Understanding how Guattari's subject-groups operate in relation to subjugated groups enables us to comprehend the mechanisms of information transmission, messaging systems, their utterances and semiostics, and the effects that result in either capitalistic subjectivity or, conversely, free, thriving subjects. The opening up of researchers as subject-groups in a transversal mode challenges the field of SRF to enable it to find solutions that express each individual's desire to experience the pleasure of a third-thumb and to find solutions that will enable that.

Closing remarks

In the discussion on transversality and group therapy, I note several issues that were carried through the analysis, which can offer openings into the discourse around systems of transmission between groups. The first is that Guattari encouraged flexible and non-authoritarian systems that presuppose transversality. On that note, we can safely assume, as Guattari suggested in the discourse that has

[986] Guattari, *Molecular Revolution in Brazil*, 1, p390-91.
[987] Guattari, *Molecular Revolution in Brazil*, 1, p91.

been so far analysed, that the field of science can indeed open the communicative messaging pathways that have escaped 'from oppressive hierarchies—non-arborescent, "rhizomatic," "transversalist" models'[988] if allowed.

Second, as we have discussed, Guattari has been critical of closed systems of signifying logic, a logic that carries with it a modelised way of doing and perceiving things such as certain forms of transmission and transference. From my review, it is apparent that the same signifying logic is pervasive in the aims and ways of articulating and understanding research. The groups in the field of SRF use the same methods, approaches, and language to investigate and examine problems from a very narrow set of perspectives.

Third, based on the idea of the rhizomic structures explored in Chapter 4A, which examines transversality, we can also analyse science in the image of Guattari's arborescent structures and rogue subject groups that dominate them- much like Freudian and Lacanian superstructures of the psyche, as heavily critiqued by Guattari. SRF epistemology also exhibits superstructures that are highly circumscribed and closed[989] with its foundational laws and principles. Science is similar to the arborescent tree trunk, rightly or wrongly, embalmed in groups that control. Science is built on foundational laws of physics that are rarely challenged. This does not preclude the practice of science from being more rhizomatic, with interdisciplinary approaches, experimentation, and research that develops into fields worthy of study for their own sake, rather than for profit. I am especially referring to research dictated by the political systems of capital-driven grants.

Fourth, I would suggest that the field of SRF and the science that supports it is a type of groupthink conducted by researchers and institutions too scared to break the mould. Too scared to take risks, befalling the political ramifications, thus conceding to the politics of dominant subjectivity and becoming a machine that 'reifies stratum'[990] at the heart of science. Thus, it is often left to the territorialisation of capital and captains of private industry to take the risks that make it more conducive and permissive for research to break the rules, driven purely by profit, which steers all research in another direction, into states of capture.

Fifth, when scientific revolutions are so forceful that they enact change, it is then and only then that new concepts gain acceptance, much like groups that oscillate between being subjugated groups, which, through transversality, break free to become subject-groups—masters of their own destinies. It is only right that science demands a high level of rigour, but this should not stop with the creative

[988] Guattari, *Molecular Revolution in Brazil*, 1, p274.
[989] Guattari, *Molecular Revolution in Brazil*, 1, p197.
[990] Guattari, *Molecular Revolution in Brazil*, 1, p335.

means of transversal thought. But there is no denying that the gatekeepers' transmission of models in science remains a point of resistance to transversal thinking. The need for more rhizomic concatenation in material technologies and experimentation with the fundamentals of physics and quantum physics may help us develop technologies that express latent desires. These advancements not only help alter transmission systems but also give rise to modes of technology, such as wearable third-thumbs, that change our relationship to our subjectivities. This cannot occur in a vacuum. It requires the foresight that Guattari suggests a 'complete *activity of metabolism of the change in the perception of situations*' to comprehend thoughts differently and see matters in a new light. [991] It also means finding new ways to transfer information in refreshing ways when we teach them. In his discussion about minorities, Guattari tells his audience in Brazil that education and appreciation for diverse subjectivity start with participation in childhood institutions. We can broaden the meaning of the following passage to understand the wider impact on all types of education. Guattari relates these ideas in this way:

> It seems to me to be really necessary for all pedagogic or microsocial experimentation to take up a position in relation to this kind of problematic [refering the models of education]. To be unaware of it means running the risk of it intervening in the modelization, the transmission of models […] implications that this might have in the libidinal economy.[992]

Guattari wants to experiment, think, and investigate how we learn and teach. He encourages us to question and intervene in the habits of the teaching system, so we are more aware, critical, and not to accept everything we hear, see, or learn unwaveringly.

Guattari encourages us to escape the pitfalls of encirclement that encapsulate the echo chambers and epistemic bubbles[993] found in subjugated groups as well as in subject-groups, and institutions with examples from psychiatric hospitals and those of the analyst and analysand. Thi Nugen defines echo chambers and epistemic bubbles, both of which can be applied to the politics of science in arguably similar ways. He differentiates epistemic bubbles and echo chambers in the following way:

> An *epistemic bubble* is a social epistemic structure in which other relevant voices have been left out, perhaps accidentally. An *echo chamber* is a social epistemic structure from which other relevant voices have been actively excluded and discredited. Members of epistemic bubbles lack exposure to relevant information and arguments. Members of echo chambers, on the other hand, have been

[991] Guattari, *Molecular Revolution in Brazil*, 1, p177.
[992] Guattari, *Molecular Revolution in Brazil*, 1, p139.
[993] C. Thi Nguyen, "Echo Chambers and Epistemic Bubbles," *Episteme* 17, no. 2 (2020): p141, https://doi.org/10.1017/epi.2018.32, https://www.cambridge.org/core/article/echo-chambers-and-epistemic-bubbles/5D4AC3A808C538E17C50A7C09EC706F0.

> brought to systematically distrust all outside sources. In epistemic bubbles, other voices are not heard; in echo chambers, other voices are actively undermined.[994]

The notion of Guattarian subjectivity relates to the dynamics of subject-groups and subjugated groups, which are part of this scientific revolution produced through a struggle for expression. And though we discovered from Guattari that groups don't necessarily directly create subjectivity, they are part of the 'assemblage that may, at a certain point, acquire the dimension of an analytic process'[995] that is part of the dynamics and mediations of group messaging.

Any revolution in SRF technology would necessitate a change in how systems of power transmission, control signals, actuators, and motors work in SRFs. It is hoped that this would preclude the use of wires, find better ways of transmission, and make wearability significantly easier. However, as I mentioned in the introduction to this section, any discussion of transversality and Guattarian group interactions must consider the transmission of epistemology and the transfer of knowledge. Guattari's ideas on groups and transversality provide an understanding of the dynamics and effects of environments on individuals. The analytical group dynamics, if permissible, are a presupposition for the expression of collective desires, resistance, and activism in transversality. The revolutions speculated from this type of subjective turn would have dramatic social, political, and economic impacts, changing the research on the types of technologies, such as the production of SRFs. The impact is universal; for once we initiate change at the levels of transversality across groups and institutions, there may be a ripple effect. By influencing other groups, the effects will be felt across various groups and institutions in all industries, including electronics, commerce, research and development, and others. This is on the proviso that the micropolitical insurgency of Guattari and Rolnik is mobilised in every individual working in transversal cooperation. Guattari and Rolnik's micropolitical revolution can instigate a new technological and even an industrial revolution.

For Guattari, scientific revolutions don't guarantee freedom and emancipation from a socio-political life dominated by the hegemonies of capital and dogma. Guattari tells us that the scientific revolution can be a double-edged sword. He explains that we must work at such endeavours as

> [t]he hope of "light at the end of the tunnel," and the myth of the "great recovery" (but recovery of what and for whom?) hide from us the irreversible character of the situation that was engendered by the continuous acceleration of technical and scientific revolutions. "From now on everything will be different." Great! But there are two possibilities: either these disturbances will be complemented by mutations of social subjectivity capable of leading them "far from equilibriums" currently existing,

[994] Nguyen, "Echo Chambers and Epistemic Bubbles," p141.
[995] Guattari, *Molecular Revolution in Brazil*, 1, p389.

> toward emancipative or creative paths; or else, progressing from crisis to crisis, these disturbances will oscillate around a point of conservatism, a state of repressive stratification and depression, with increasingly mutilating, paralysing effects.[996]

Despite this double-edged sword, from what I understand from their book on the *Molecular Revolution in Brazil,* the practice of free, autonomous and thriving subjectivities must be placed in the hands of schizoanalytic practice (discussed in Chapter 4A) and suffused with its molecular activism to remain mobile and transversal. To try, to experiment, and to fail if one must — yet we must push for transversality in science.

Conclusion

In the spirit of Guattarian semiotic analysis, the phonemes *trans,* used as jargon in the related field of science and engineering, are notions containing revolutionary and transformational endeavours if only they were freed from the semiotic redundancies that ground them in current power structures of control. Guattari's message in the passage below conveys the idea that scientific machines and subjectivities can liberate and remake the world if they are actively pursued. The mobilisation of techno-subjectivities and the revolution of the architectures of the third-thumb place the hopes of societies at the sharp edge of micropolitical revolution with their hopes for transversality and evolution. These are the deep issues at the intersection of the psyche, politics, ethics, and economies of varying markets, including that of desire—resisting 'social control'.[997] The augmentation of the third-thumb with that of individual identity and social constructs requires initiatives, the forces of hope, individual and collective cooperation and the required work by institutions to push forth into the next epoch in scientific endeavours. Guattari encourages initiative and drive to bring about the revolutions in science when he concludes:

> I don't think that scientific progress and technology are necessarily accompanied by a reinforcement of the schiz in relation to the values of desire, of creation. On the contrary, I believe that it's necessary to use machines, all machines, concrete and abstract, technical, scientific and artistic, to do much more than revolutionize the world: to recreate it from point to point.[998]

Thus, what Guattari is suggesting is that we must strive to make science a field of transversality to encourage innovation. Transmission is the word that carries with it both the revolutionary aspiration

[996] Guattari, *Molecular Revolution in Brazil*, 1, p274.
[997] Guattari, *Molecular Revolution in Brazil*, 1, p271.
[998] Guattari, *Molecular Revolution in Brazil*, 1, p408.

of abstract theoretical machines and physical, manifest, concrete machines, like the paradigm of a trans-augmentative third-humb. Transference bore fresh fruit when it was extended to transversality, carrying the hopes for understanding the psyche in its environmental contexts, including politics, a diverse set of social and societal factors, and the right to autonomy. By placing transversality outside the bounds of the familial entrapments that optimise transference, we can also place transmission to form new paradigms in technology, the technics of augmentation and subjectivity. Groups and institutions offer us a deeper understanding of the dynamics of power and the operation of transversal action, which aims to transform society's frameworks and support subjectivities in their projects of self-construction and enunciation, thereby creating rich, interconnected lives. Understanding the dynamics of how they function, convey messages, communicate, and transmit information about the foundational drivers for social exchange that originate at the level of the psyche and involve analytical foresight is crucial to understanding how to create free, autonomous subjects. In turn, these flourishing subjects can interject into the processes of subjectivation that determine the machines of life, the theoretical machines (discussed in Chapter 4B), the electronic machines of transmission systems, power systems, and the epistemic transmission machines of knowledge, including the theoretical and aesthetic machines (Chapter 4B). By targeting these analytical expositions, transversality can open up references to knowledge of ourselves, our relations to the world and the challenges before us. Transversality and its transmission via group therapeutics alter and weave through a creative mesh that represents the complex textures and the fabrics of societies and social relationships. Transversality through group therapeutics (and its semiotics) encompasses multivalent indices of exchange in analysis, offering a more dynamic hope for finding solutions to our challenges through free exploration and expression. As noted in Chapter 4A by Patrick Ffrench, '[t]ransversality, in other words, is the therapeutic and existential precursor to the rhizome and to schizoanalysis.'[999] Hence, from the analysis presented in this chapter, we can now say that transversality encompasses the therapeutics of groups and institutions in helping construct techno-subjectivities and free, diverse societies.

[999] Ffrench, "Guattari's Therapeutics: From Transference to Transversality," p219.

Chapter 4D - Using Fish Fins, the Otariidae Eared Seal flippers, and playing the piano with a six-fingered hand in the service of SRF innovation

Introduction

This chapter specifically explores the barriers to transversality and demonstrates how innovations in SRF technology offer hope for the emergence of singularization of subjectivity. It does this by further exploring Rolnik and Guattari's ideas on subjectivity before turning to explore innovations in SRF and their foundations in subjectivity. It examines the everyday structures that hinder the elevation and operation of transversality, leading to the repression of individuals, subjects, and groups in society. By exploring the hold that modern-day capitalistic societies (explored as IWC in Chapter 2) have on subjectivity, we can appreciate the barriers that need to be traversed in open, free societies that operate transversally. This psychoanalytic operation is present in some sectors of society and is specifically identified in particular SRF projects showcased in this chapter, demonstrating the various functions of transversality, while speculating on how they can transform and revolutionise societies' and individuals' subjectivity. By examining each project from a psychoanalytic perspective, we can demonstrate how emerging social and political changes can evolve into Guattarian revolutionary modes of existence.

In this chapter, I will attempt to extend the ideas of Guattari's group analytics, as discussed in the previous chapter, by incorporating the concept of the *unconscious coefficient of transversality*. This concept of *coefficients of transversality* is based on Guattari's understanding of transversality as a connection between individuals and groups. It represents the level of *openness*. This type of coefficient can be thought of as an affiliation and compassion for the other, referring to people, ideas, and sets of social constructs that are found in the realm of *otherness*. In particular, I shall explore how the coefficients of transversality set about to dismantle the social construct that Guattari sees as those structures that control and capture subjectivity. I will describe how these structures and systems operate in the field of SRF. Using three particularly focused research papers, I examine how coefficients of transversality can disrupt the grip of pyramidal hierarchies that capture subjectivity. I shall discuss the inventiveness of the three research instances, the Fin Ray Effect, Otariidae-inspired Soft Robotic Supernumerary Flippers using fabric kirigami and origami, and Playing the Piano using the SR3T (Supernumerary Robotic 3rd Thumb), and the reasons why these

three are suitable examples of how unconscious coefficients of transversality operate in the real world.

Guattari's elucidation of how social pyramidical structures constrain transversality

Marxism and the infrastructure complex

Guattari sees transference as a model manifested in 'our industrial society',[1000] linking Karl Marx's concept of surplus value to Lacan's concept of *jouissance* (or surplus enjoyment, which incessantly moves towards Freud's death drive).[1001] The prohibition of jouissance[1002] creates the meta-psychoanalytical concept of *the lack*.[1003] *The lack* for Lacan inspires desire, mobilising desire to seek out what is lacking. In terms of Freudian and Lacanian ideals, the lack stands in for signifiers such that it generates the castration complex in the child through a symbolic order, where, for example, the lack of the mother not having a penis inspires fear. The lack perpetuates the need to refill the metaphorical container of subjectivity with what is lacking. It is tightly coupled with satiation, ideally through Marx's production and consumption, as suggested by Guattari[1004]—a never-ending quest for fulfilment of goods and products to compensate for the lack. For Guattari, capitalistic subjectivity features the lack becoming part of the Freudian death drive[1005], as desire that can never be quenched, leading one to fall into a black hole of conspicuous consumption. Although the idea of lack isn't taken up or pursued other than in his criticism of its limits, Guattari instead counter the ideas of jouissance and the lack by repeatedly referring us to his understanding of desire (there for always criticizing the lack) as a limitless engine that creates and proliferates subjectivity as both a generating and a multiplicitous differentiating force, rather than one that is always *lacking*. This is central to his ideas of transversality, as discussed in previous chapters.[1006] Guattari suggests that 'desire has infinite possibilities of assembly' and that it generates and fulfils the individual.[1007] Desire, in the form of desiring machines, as discussed in Chapter 4B, becomes the defining system by which

[1000] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p84.
[1001] Guattari, *Molecular Revolution in Brazil*, 1, p303.
[1002] 'In psychoanalysis this opposition is interpreted as a prohibition on jouissance—the pleasure principle regards jouissance as excessive and destabilizing. On this view, pleasure can only be pleasurable so long as it is not too pleasurable. In contrast, jouissance can only be jouissance if it goes beyond mere pleasure and risks death and courts disaster.' "jouissance," (2: Oxford University Press, 2018).
[1003] Christina Soto van der Plas et al., *The Marx Through Lacan Vocabulary: A Compass for Libidinal and Political Economies*, 1 ed., Lines of the Symbolic Series, (United Kingdom: Routledge, 2022), p248-49.
[1004] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p84.
[1005] Guattari, *Molecular Revolution in Brazil*, 1, p354.
[1006] Guattari, *Molecular Revolution in Brazil*, 1, p353.
[1007] Guattari, *Molecular Revolution in Brazil*, 1, p354.

a multivarious world of connections is formulated, sweeping up all surplus desires (jouissance) and connective possibilities that construct subjectivity while enhancing transversality.[1008] Unlike Marx and Freud, they do not become the abyss of the death drive but rather a constituting force for giving and inspiring life. For Guattari, all desires are formulae for connections and create alliances in the 'processes of subjectivation'[1009] (the process of building subjective experiences and understanding), including machines of capitalistic desire, which have a rich and complex system of connections.

In summary, for Guattari, desire and the process of subjectivation—the process of constructing subjective internal and external worlds—can be seduced by capital yet remain integral to the production of subjectivity. For Freud and Lacan, uncontained desire can only lead 'to chaos, a drive disorder, reified in the form of a death drive'.[1010] Whichever way you look at it either through the concept of lack or Guattarian ideals on desire and how subjectivity is borne -capital has the insidious capacity to overtake subjectivity through hijacking desire, creating a structured social system that can be controlled through channelling jouissance into a desire for particular fetishisation of consumption and production, shutting down all other types of desire that may represent subjective unconscious expressions. As Chantelle Gray and Aragon Eloff suggest, in their chapter 'Fabulation in a Time of Algorithmic Ecology: Making the Future Possible Again', in which they build on the work of Guattari:

> The individualist, individualising societies we currently find ourselves in have not only lost their means of tertiary protention, but a memory of what a society is and can be: that which allows the development and cocreation of individual and social freedom; where material goods are produced in order to meet the physical needs of everyone in a society, rather than satisfy the insatiable requirements of capitalism; where free and equal social relationships are fostered so that people can flourish mentally and emotionally and, in turn, develop their ethical and creative capacities.[1011]

Semiotic machines and signifiers of capital perpetuate hierarchies

In an attempt to reveal the extent of capital's hold on subjectivity, Guattari explains the processes of capitalistic subjectivation in this somewhat complex statement with many resonances:

> Everything that is produced by capitalistic subjectivation—everything that comes to us through language, the family, and the facilities around us—is not just a question of ideas or of transmission of

[1008] Guattari, *Molecular Revolution in Brazil*, 1, p465.
[1009] Guattari, *Molecular Revolution in Brazil*, 1, p264,p389,p469.
[1010] Guattari, *Molecular Revolution in Brazil*, 1, p303.
[1011] Chantelle Gray et al., "Fabulation in a Time of Algorithmic Ecology: Making the Future Possible Again," (Switzerland: Springer International Publishing AG, 2022), p129.

> meanings by way of signifying statements. Nor can it be reduced to models of identity, or identifications with maternal and paternal poles. It has to do with systems of direct connection between the great machines of production, the great machines of social control, and the psychic agencies that define the way of perceiving the world.[1012]

Guattari points out in the above quotation from *The Molecular Revolution in Brazil* that, beyond the question of signifying systems that model our thoughts and beyond the psychoanalytical Oedipal poles used in transference that model our unconscious psyche, our habits of thinking and our perceptions are also deeply influenced by forces of capital. He is trying to suggest that capital is deeply ingrained with subjectivity through our everyday relationships with work, politics, psychological and psychosocial agencies, collective thoughts, the law, and so on, creating a context that shapes how we view the world. Despite this, Guattari makes a case for escaping the insidious grip of capital's hold on the individual's subjectivity, and suggests this is achieved through transversality. I would argue that certain aspects of capitalistic subjectivity create opportunities or ruptures of escape into the transversal world of connections, such as those that have manifested in the creation of free subjects through the power of communication in new technologies. This type of Guattarian argument can be used to counter his arguments, demonstrating the flexibility of connections in transversality and the transversal relationship between the macro and micro levels. Either way, these connections (and their capitalistic ruptures) create free, singularized, unique individuals divorced from the capitalistic ego ideals. The opportunity for subjective transversality before it is captured (in a totalising fashion) by capital is the liminal moment that Guattari envisions as an escape.

Guattari warns that the mechanisms instilled in the process of capturing subjectivity are expressed in the processes of the transferential phenomenon of the industrial complex, which is already entrenched and in operation before language emerges. He suggests that the transmission of semiotics (the more expansive model of signs as proposed by Louis Hjelmslev's glossmatics, which serves as the starting point for deeper social and linguistic analysis)[1013] at such an early stage paves the way for capitalistic subjectivity. Guattari suggests that the phenomenon of the industrial complex is taught in the mode of communication and messaging from the moment the child is born, calling it 'the fundamental models of our industrial society.[…] The message concerns industrial society […] We are here already in the signifier, though not yet in speech or in language.'[1014] And

[1012] Guattari, *Molecular Revolution in Brazil*, 1, p37.
[1013] Jürgen Trabant, "Louis Hjelmslev: Glossematics as General Semiotics," Topics in Contemporary Semiotics (Boston, MA: Springer US).
[1014] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p84.

this, declares Guattari, 'has to do with transference, transmission, or exchange'[1015] of semiotics that is operative very early in life. For Guattari, the limitations of 'speech, image and transference in [the hu]man'[1016] are the basis of the silent expression of desire. For this reason, Guattari rails against the forces of capital that control desire, and thus encourages individuals to express their desires to escape the servitude of desire to labour in the industrial infrastructure complex.

Even when speech develops, there is an even stronger imprinting of capital and its signs via certain signifiers expressed in language that takes hold in a way that strangles and overprints any expression of true creative desire in the unconscious. This is instilled in the way we reference things, and the aspirations and prestige we see in these signifiers, thinking they are true representations of our desires: cars, job titles, and salaries. These become impasses for desire that is controlled and directed by capital, which requires other sources of intervention to help subjectivity escape its control. Here, Guattari throws up a wildcard, citing the aid of technologies, saying that 'cybernetic machines'[1017] may resolve these problems. Hoping that cybernetics will deconstruct hegemonic desires, Guattari looks to technologies such as those that contain machine language (binary codes) and abstract structures. He believed they are systems that, through their non-human, non-habitual operations, may subvert humanity's impasses linked to 'structural laws of linguistics or etymology'[1018]—structural laws of capital that control social strata through semiotics of language expressed in groups and institutions. We should stay with the idea of why Guattari sees cybernetic machines as machines of recovery. In the previous chapter, we discussed Rolnik's definition and role of 'semiological redundancies' that territorialise our imagination with representation equivalents, always contentless and 'without any operational impact'.[1019] In the passage below, Rolnik provides the example of contentless expression in advertising, which is merely a representative of content, not the meaningful referent itself. Unlike contentless semiological redundancies, 'diagrammatic interactions make sign systems work directly with the realities to which they refer'.[1020] Giving us instances of diagrammatic versus semiological interactions, Rolnik says:

> Examples: mathematical algorithms, technological plans, and computer programs participate directly in the process of creating their object, whereas an advertising image can only give an extrinsic representation of its object (but then it is a producer of subjectivity).[1021]

[1015] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p84.
[1016] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p85.
[1017] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p85.
[1018] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p84.
[1019] Guattari, *Molecular Revolution in Brazil*, 1, p471.
[1020] Guattari, *Molecular Revolution in Brazil*, 1, p471.
[1021] Guattari, *Molecular Revolution in Brazil*, 1, p471.

We can think of semiological redundancies as mirages where diagrammactic interactions are systems of reference that work to create meaning (discussed in Chapter 4C). From Rolnik and Guattari's references to computer programs and cybernetic machines, we gain insight into their ideas on why machines provide hope for the escape of subjectivity from servitude from meaningless mirages. Through machines, one can connect subjectivity in extra-linguistic ways that escape the grip of semiologies (semiological redundancies – the structured signified and signification systems that territorialise other proxies of content as opposed to the content itself) and establish diagrammatic connections that provide lines of flight out of the void of subjective capture. In this way, machines can help desires drive connections to social structures outside systems of control and create real, meaningful relationships with content and affect, allowing subjectivity to flourish beyond the superfluous framework of capital's redundancies. Rolnik and Guattari reference these cybernetic machinic systems because of their ability to be at arm's length (ideally) from the absurdities that capture subjectivity (ideally). This space, provided by the abstract systems of cybernetics, enables other potential connections that transcend the realm of semiotics. These territories of capture are circulated through ideas held by capital and logocentrism, racialising-colonial, phallocentric systems that subjugate the individual. These cybernetic and technological systems can bring heterogeneous systems of equivalents into connection, creating pathways for subjectivity to expand and escape into new territories of desire that lie outside prescribed systems of desire (think of possibilities brought by AI). Again, this is an idealised image. Today, we find that cybernetic machines also have the potential to capture subjectivity (some aspects of epistemic bubbles and echo chambers found in social media).

Diminished revolutionary potential due to hierarchies

Guattari always held high hopes for the Marxist promise of the 'revolutionary potential'[1022] of the working classes, but his hopes have fallen short of being realised. Having been disillusioned by capitalism's appropriation of the radical potential of the middle classes, he proposes a new revolution —a molecular revolution (small changes at the local level) bound by transversality — that can lead to a type of subjective micropolitical revolution, one individual at a time. Without this capacity to initiate change, groups cannot function as institutional objects of relation (form alliances) with individuals or collectives. Guattari explains:

> *it is obvious that the guaranteed working class no longer has this revolutionary potential at all,* because it lives in a state of dependence and counterdependence [sic] on the elite systems […] It is

[1022] Guattari, *Molecular Revolution in Brazil*, 1, p264.

> the non-guaranteed working class, or the guaranteed working class that rejects the system of guarantees, that is the vehicle of the revolutionary aspiration that concern all modes of subjectivation.[1023]

Guattari is despairing at the fact that subjectivities have been robbed of their capacity to bring about political change. He presupposes the need for radical yet subtle changes to emerge through transversal subjectivities as a key to societal transformation. The subtle change is instigated through actions that mark each individual's will to break free from habitual ideals thrust upon them by hierarchical structures. In the passages above, Guattari suggests that the non-guaranteed working classes, the ones on the outside of the systems of entrenched capital and its markets (such as gig workers), or those who disagree with systems of capital, are the guardians of transformation because they still maintain their revolutionary potential. I shall describe them as 'militant political activists' following Deleuze's description of Guattari himself as an exemplar.[1024] Guattari advances his idea, suggesting that it is only through revolutionary activism that 'enable us to conceive of alliances and systems of transversality that are able to pass between any social categories because what unites is the subjective position, the position of desire'.[1025] Through our desire to connect with collectives across all sections of society, alliances are formed that change our worldviews. Guattari suggests in the earlier passage on the 'guaranteed working classes' that the industrial complex, in which production and consumption machines are tightly coupled, allows elites to exploit their power structures and silence the 'guaranteed working class', thus disabling decent. For example, if you disagree with these laws that aim to increase your super profit, we cannot guarantee your job. When the elites patronise the non-guaranteed class, they are subjugating them, subduing their voices, and pacifying them into compliance. The alienation this acquiescence brings takes over the collective alliances that would otherwise work in cooperation. If permitted, the cooperation would instead seek common ground and build capacity for a collective rebuke that expresses desires for self-sovereignty and autonomy. In the dysfunctional system Guattari critiques, the exchange for non-guaranteed cohorts' patronage ensures that elites grant workers access to basic infrastructure, while leaving the rest to fend for themselves in the precarity of economic deprivation, voicelessness, and hopelessness as punishment for their lack of support. This is especially true for those who sit in the lower hierarchies or have a *horizontality* (can be thought of as the dispersed sideways ineffectual struggling of voices) of powerlessness (a Guattarian idea discussed further in the next section). These are the ways subjectivities in the political economies of capital are constructed and

[1023] Guattari, *Molecular Revolution in Brazil*, 1, p264.
[1024] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p7.
[1025] Guattari, *Molecular Revolution in Brazil*, 1, p264-65.

constrained. The elites have solidified and controlled workers through precarious structures they have created to control labour acts with an unequal and unfair system of exchange, ensnaring them into hierarchies of structures of 'master-servant relations'[1026] (guarantees) that only serve to secure the rise and power structures of those who sit atop the systems of hierarchies. These systems overlook the potential for change, as they silence the voices of dissent. As indicated by Guattari, they dismiss any latent potential for revolution, thereby ensuring the elite's unfettered access to capital and power (IWC). Most importantly, they guarantee a model of subjectivity that working classes are assigned (not chosen by desire), much like the uniform workers wear in a labour camp.

Coefficients of transversality - dismantling horizontality and verticality

So far in this chapter, we have traced just a few of the ways Guattari views the constraining forces on subjectivity, which hamper the individual from realising their true destinies and expressing their collective desires. The economic structures discussed refer to Guattari's ideas on *vertical* and *horizontal* pyramidal hierarchical structures, bolstered by capital with its semiotic redundancies, which take hold of the psyche, the individual's desire, and ego, thereby undermining the revolutionary potential of the working classes. In the coming section, I would like to examine how Guattari sees the *horizontality* and *verticality* in the structures that constrain our lives can be altered through transitions to transversality. By examining these ideas, we can begin to understand how to overcome the barriers of pyramidal hierarchies that shape the context of subjectivity and break free from its confines. By integrating ideas on group analytical processes (discussed in Chapter 4C) with the concept of coefficients of transversality, a more holistic understanding of Guattari's vision for moving toward flourishing individuals and thriving societies can be achieved.

For now, we can think of these *coefficients of transversality* as a coefficient that represents openness, responsiveness, and receptiveness as a position for Guattarian subjectivities. We can also think of *horizontality* and *verticality* that are antithetical to coefficients of transversality as the structural description of social, political and economic pyramidal structures, in which the verticality limits the mobility of the working classes in favour of the dominant classes (elites), whilst the horizontality represents the entrapment of the voiceless and powerless classes that undergird society (the guaranteed and non-guaranteed working classes) trapped in the carousel of life.

In Chapter 4C on group therapeutics, I introduced the operational processes of Guattarian group analytics. The predicament of subject groups who fall into subjugation was explored. Guattari

[1026] Guattari, *Molecular Revolution in Brazil*, 1, p49.

offered us an understanding of how transversality could reverse this fall into subjugation. Now, Guattari offers us additional functions of transversality that further add to the functions of group dynamics. His elucidation of the micropolitics of activism and the enfranchisement of subjectivity through the dynamics of coefficients of transversality offers additional clues to freeing subjects from the monotony of their disconnected contexts. Guattari suggests that the transversal escape from hierarchies formed in places by the formidable stasis of capital, which takes hold of classes, groups, organisations, and institutions, is achieved by averting the 'verticality' and 'horizontality' of such systems.[1027] These are fundamental ideas that transversality opposes (verticality and horizontality), often hidden within the vertical towers that represent the pyramidal structures of organisational control in political and social structures, which are often hard to perceive beneath the deceitful veil of their significations and semiological redundancies. Guattari even gives us an example of the horizontal swathes of powerlessness in 'disturbed wards of hospitals' where mental health patients languish, and in his representations of the working classes.[1028] In his 'Transversalité' paper, published in *Molecular Revolution Psychiatry and Politics*[1029] , the vertical is defined as the hierarchical organisation of an institution (managers above senior clinicians, clinicians above patients, etc.), and the horizontal is the formation of 'wings' or 'departments' within an institution. Guattari defines it in this way:

> (a) verticality, as described in the organogramme of a pyramidal structure (leaders, assistants, etc.);
> (b) horizontality, as it exists in the disturbed wards of a hospital, or, even more, in the senile wards; in other words a state of affairs in which things and people fit in as best they can with the situation in which they find themselves.[1030]

Guattari believes in the 'abolition of hierarchical privilege',[1031] the vertical privilege that limits the possibilities of mobilisation to cross-connect across the domains that are traditionally designed to contain subjectivities. He equally believes that people should not just put up with the 'situation they find themselves', especially if it is detrimental and infantilising. The breakdown of such structures that inhibit subjective assemblage is the precursor to the establishment of transversality. Without it, the analytical processes identified in group dynamics (discussed in the previous Chapter 4C) cannot engender change.

[1027] Guattari, *Molecular revolution : psychiatry and politics*, p17.
[1028] Guattari, *Molecular revolution : psychiatry and politics*, p17.
[1029] Guattari, *Molecular revolution : psychiatry and politics*, p11-23.
[1030] Guattari, *Molecular revolution : psychiatry and politics*, p17.
[1031] Guattari, *Molecular revolution : psychiatry and politics*, p21.

Guattari proposes that transversality is engaged in the project of 'different meanings' from the service of cross-communication and changes in 'coefficients of unconscious transversality'.[1032] We can add to the definition of 'coefficients of unconscious transversality' (openness, responsiveness, reproachment and receptiveness) as a moving function of ruptures that includes otherness, resting on a sliding scale that captures the level of understanding and on the flip side, a collective unconscious blindness to the 'other'. The coefficients of transversality cross all boundaries of 'micropolitics of apprehension of oneself, of the cosmos and of otherness',[1033] meaning a type of conciliation that represents rapprochement and understanding of the polity of self-governing and relations to the otherness that includes the appreciation of difference found in the collective. In his 'Transversalité' paper, Guattari explains how the coefficient of unconscious transversality can prevent horizontality and verticality by saying:

> Transversality is a dimension that tries to overcome both the impasse of pure verticality and that of mere horizontality: it tends to be achieved when there is maximum communication among different levels and, above all, in different meanings. It is this that an independent group [or subject group] is working towards. My hypothesis is this: it is possible to change the various coefficients of unconscious transversality at the various levels of an institution.[1034]

The changes in revolutionary content that the Marxist-Guattari seeks are the seeds for the development and cross-pollination of ideas and conditions that benefit all (peoples, classes, races, genders), not just one group, but across all levels of institutions. These conditions arise from an insurgency and activism (micropolitics) in our subjectivities through changing coefficients of unconscious transversality or by simply opening the blindfold so we can see the other faithfully. However, the Guattarian revolution of subjectivity through transversal movements across increased coefficients of transversality is not led by bloodletting, but rather by the subtle changes brought about by the transversal processes of subjectivation that manifest in every act of the self-reliant and ethical individual (the ethico-aesthetic discussed in Chapter 2). Guattari speaks of the transversality that enables the individual to participate in their own renewal – the actualisation of the self, self-image, self-styling, self-making, and self-configuring that aligns with their unconscious desires.

Guattari encourages us to approach the analysis of subject groups and subjugated groups, as well as the guaranteed and non-guaranteed classes, institutions, and groups, by breaking down the horizontality and verticality of structures to find common ground at points of intersection for flourishing societies through communication, while benefiting the collective. The more different the

[1032] Guattari, *Molecular revolution : psychiatry and politics*, p18.
[1033] Guattari, *Molecular Revolution in Brazil*, 1, p374.
[1034] Guattari, *Molecular revolution : psychiatry and politics*, p18.

likely allies discovered in this cross-pollination and activism process (micropolitics), the more spectacular the outcome. As Guattari states, '[t]ransformations that are established simultaneously between the most heterogeneous domains that one could conceive. These transformations presuppose various modalities of "transversality" between those domains',[1035] which construct uniquely singular individuals and collectively entwined (connected) subjects who can recognise and respond to each *other* and create new autonomous subjectivities from within those alliances.

Innovations in the field of SRFs

There are many interesting aspects of the research on Supernumerary Robotic Fingers (SRFs), including diversification in thought, inspirations for research, purposes of the research, the transmission of ideas, and the methods used to conduct that research. In the previous chapter, I looked at the problems along the themes of transmission. I have already led us through the transmission of knowledge and its associated problems, as well as the complex way power transmission systems interact with actuators, motors, and the wiring that connects them to their source of energy—the battery and the SRF. Now, I would like to introduce you to what I believe are pivotal moments in the SRF field of research by examining the innovations that some research groups have employed to approach the paradigm of a third-thumb.

Fin Ray Effect

An SRF paper by biologist Leif Kniese takes inspiration from the Fin Ray Effect, which is found in the structure of the fish fin.[1036] The Fin Ray structure resembles an elongated isosceles triangular structure with its two longest edges bridged by rib-like structures. This rather efficient structural configuration ensures it responds spectacularly to deformation.[1037] Crooks et al. describe the structural superiority of this structure, as shown in Figure 45, which enables us to understand why it has so insightfully adapted into a gripper or an extra finger in Hussain et al.'s SRF prototype[1038] (discussed in Chapter 3).

[1035] Guattari, *Molecular Revolution in Brazil*, 1, p397.
[1036] Whitney Crooks et al., "Fin Ray® effect inspired soft robotic gripper: From the robosoft grand challenge toward optimization," *Frontiers in robotics and AI* 3 (2016): p2, https://doi.org/10.3389/frobt.2016.00070.
[1037] Crooks et al., "Fin Ray® effect inspired soft robotic gripper: From the robosoft grand challenge toward optimization."
[1038] Hussain et al., "Design and Prototype of Supernumerary Robotic Finger (SRF) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment."

The structure of the fish fin is composed of two bones arranged in a V shape with connective tissue in between. Pulling on one side of the V causes the fin to deform. Kniese adapted this into an A-frame structure with crossbeams spaced between the tip and base, as shown in Figure 45-A. Applying a force to the structure causes the structure to bend, as shown in Figure 45-B. The traditional structure shown in Figure 45 is symmetric and capable of bending equally in either direction.[1039]

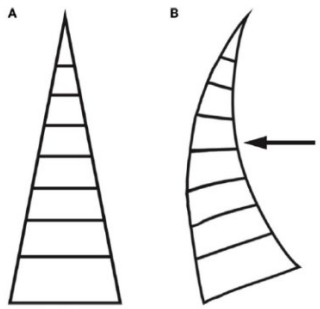

Figure 46 A&B - Fin Ray structure and effect, taken from Crooks et al.[1040] The Fin Ray® Effect can be demonstrated by applying a force to the structure shown. The force causes the sides of the structure to bend, resulting in the base and tip deforming toward the applied load. (A) An unloaded Fin Ray® structure. (B) A loaded Fin Ray® structure.

Hussain et al. utilise the Fin Ray Effect model to address the torsion forces that technically hinder the design of soft-grippers.[1041] They have adopted this design and adapted it in combination with a flexible plastic material that comprises not only the structural strength of the Fin Ray effect but also the malleability, flexibility and compliance when it comes into contact with the object that is being grasped (especially rounded objects). They implement this design to make a highly functional gripper, as seen in Figure 46.

[1039] Crooks et al., "Fin Ray® effect inspired soft robotic gripper: From the robosoft grand challenge toward optimization," p2.
[1040] Crooks et al., "Fin Ray® effect inspired soft robotic gripper: From the robosoft grand challenge toward optimization," p2 Figure 1.
[1041] Hussain et al., "Design and Prototype of Supernumerary Robotic Finger (SRF) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment."

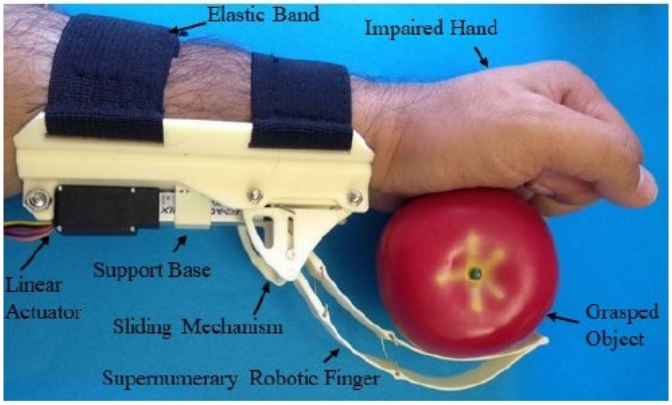

Figure 47 - Supernumerary Robotic Finger (SRF) inspired by Fin Ray Effect, taken from Hussain et al.[1042] The prototype of the underactuated compliant closed-chain modular supernumerary robotic finger (SRF). The finger is actuated through a single actuator. The finger's structure is compliant and rectangular, with stiff crossbeams that buckle and deform to conform around objects—the SRF and the human arm function as two components of the gripper to grasp an object.

Utilising this innovative structure addresses technical issues that enhance grip capability, improve object compliance, and reduce the need for additional motors, leveraging the underactuated model of drives (i.e., less force is required). The performance of such a technical solution significantly enhances the daily functional use of people with lost finger and hand function, providing the user with a greater grip and lifting capacity. The authors suggest that this design:

> overcome[s] the problem of unwanted compliance in torsion and lateral directions, […] This geometry has a large advantage over serial or parallel kinematic chains by being capable of adapting around a curved surface. The most appealing feature which moitivated us for this work is the structure[sic] ability to be compliant in bending direction while being stiff in lateral and torsional direction.[1043]

The Fin Ray Effect is a smart solution to a challenging problem that has confounded other gripper designs and builds upon the earlier designs of Hussain et al. (discussed in Chapter 3). The innovation in resolving the torsion forces in the gripper design that made it hard to grasp objects is an example of a transversal moment in the evolution of SRF design, focused on the users' need for comfort and stability, dealing with technical and scientific issues, and finding a solution in the anatomical structure of a fish fin. These transverse discoveries and inspirations are meaningful in overcoming the challenges that entailed SRFs, which were otherwise held tightly in the *status quo*. SRF design, inspired by such examples, prompts a pause and reconsideration of the current technical direction and aesthetic insights on SRF designs that dominate the epistemology in this field.

[1042] Hussain et al., "Design and Prototype of Supernumerary Robotic Finger (SRF) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment," p399 Figure 2.
[1043] Hussain et al., "Design and Prototype of Supernumerary Robotic Finger (SRF) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment," p399.

Otariidae-inspired Soft Robotic Supernumerary Flippers using Kirigami and Origami Fabric Manipulation

Another notable innovation in SRF design is seen in the work of researchers working on the Otariidae-inspired Soft-Robotic Supernumerary Flipper project. As Liu et al. describe this innovative configuration:

> soft actuators were designed following origami (paper folding) patterns, reinforced by kirigami (paper cutting) fabrics. With this new approach, the proposed soft flipper incorporated eight independent muscles, achieving over 20 times pay-load to self-weight ratio.[1044]

This new design is unlike a traditional human finger, but its compliance with grasping objects, dexterity, and range of movement far exceeds those of any other third-thumb or finger.[1045] So it is more functional and user-friendly. Lui et al. suggest, 'the SSR [Soft-Robotic Supernumerary] flipper is more compliant […] even more compliant than existing soft SR fingers, by avoiding all rigid components'.[1046] This is another prevailing example of transversal thought in action, which leads us to recognise the Otariida Seals' agility and sophisticated dexterity beyond the superiority of the anthropocentric domain. According to Lui et al., 'the dexterity of the fore flippers, [of the] Otariidae can perform agile and sophisticated activities'.[1047] The recognition of the performance capabilities of their flippers by researchers shows us that the Otariids (eared seals) have superior ability for 'terrestrial walking and object handling, and hugging' together with very complex underwater manoeuvers they can perform given a unique flipper anatomy that Lui et al. detail for us in their paper.[1048] Combining these ideas and structures with the material qualities in origami and kirigami design principles is staggeringly insightful. Lui et al. describe the Japanese art of folding and its incorporation into the SSR designs as comprising 'entirely of soft components, with kirigami fabric constraints over origami soft actuators, achieving superior dexterity, strength, lightweight, and foldability.'[1049] The thought process and inspirations here also demonstrate that researchers' transcultural understanding of the social domains of art and design extends beyond the mainstay fields of mechatronics and robotics—another transversal manoeuvre that utilises art and the environment.

[1044] Liu et al., "Otariidae-Inspired Soft-Robotic Supernumerary Flippers by Fabric Kirigami and Origami," p2747.
[1045] Liu et al., "Otariidae-Inspired Soft-Robotic Supernumerary Flippers by Fabric Kirigami and Origami," p2747.
[1046] Liu et al., "Otariidae-Inspired Soft-Robotic Supernumerary Flippers by Fabric Kirigami and Origami," p2749.
[1047] Liu et al., "Otariidae-Inspired Soft-Robotic Supernumerary Flippers by Fabric Kirigami and Origami," p2749.
[1048] Liu et al., "Otariidae-Inspired Soft-Robotic Supernumerary Flippers by Fabric Kirigami and Origami," p2749.
[1049] Liu et al., "Otariidae-Inspired Soft-Robotic Supernumerary Flippers by Fabric Kirigami and Origami," p2748.

Playing the paino using the SR3T (Supernumerary Robotic 3rd Thumb)

Other consequential studies show a great degree of creative foresight. The methodology used by Shafti et al. to test neurocognitive augmentation using the piano for their specific SRF design is one example of this approach. Instead of defaulting to the standard set of standard grasps that other researchers use in their testing of SRFs, which fall short of replicating the manipulation tasks necessary for activities of daily life (ADL), Shafti et al. engage the piano for their tests (or test bed). Before that, let's discuss the SRF they used in their experiments: The Supernumerary Robotic 3rd Thumb (SR3T) used by Shafti et al. was first introduced in 2018 in a paper by Cunningham et al. Cunnigham et al. propose that, '[o]ur supernumerary robotic 3rd thumb was created to augment piano playing, allowing a pianist to press piano keys beyond their natural handspan; thus leading to functional augmentation of their skills and the technical feasibility to play with 11 fingers.'[1050] They can be forgiven for vacillating and trying to reframe the target for their research by suggesting that not only is their SR3T an opportunity to augment human capability and expand the pleasure of playing the piano, but simultaneously, they say it is designed to reduce 'the number of workers required to do a particular task'.[1051] This direct assertion aims to justify and make their research commercially palatable to industry and production, thereby rendering the project commercially or scientifically worthy in the eyes of industry, and giving the impression that it is more worthy than the individual general user. Making the SR3T beneficial for the efficiency gains in producing work is a meaningless justification used to ground most researchers' work. It is an abject attempt to justify their interest and the direction of their work as if it isn't enough to create something that gives one pleasure for pleasure's sake.

This may be an example of what Guattari refers to when he speaks of *partial objects*[1052] or objects that express desire derived from their relations during childhood (such as the mother's breast), manifesting into other desires for objects (like the piano) in later life that are used as an industrial excuse to help production. Guattari alludes to this paradigm of prostitution of research in the name of industry in this way:

> Furthermore, the sum of all these part objects, starting with the picture of the body as the basis for self-identification, is itself thrown daily onto the market as fodder, alongside the hidden Stock Exchange that deals with shares in pseudo-eroticism, aesthetiscm, sport and all the rest.[1053]

[1050] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p665.
[1051] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p665.
[1052] Guattari, *Molecular Revolution in Brazil*, 1, p371.
[1053] Guattari, *Molecular revolution : psychiatry and politics*, p20.

Cunningham et al. are interested in the piano and music, which is a worthy pursuit in itself. They demonstrate their insight into how a player manipulates the musical notes like a piano. They introduce us to the musical concepts like 'fingering'. Fingering is the technique of using vigorous finger movements and hand mobilisation to locate musical notes while playing certain instruments, such as locating the keys on a piano.[1054] 'The challenge of good fingering is to make the hand movements as comfortable as possible in the flow of the music without changing hand positions too often' explains Cunningham et al.[1055] We can faithfully interpret such passages as coming from individuals who are invested and passionate about music. In their experiments, they note that '[t]he pianist demonstrated the ability to use the added finger, and the extra reach provided, in a musical fashion, adding higher notes into the chords of the left hand and playing additional notes with melodies.'[1056] The discussion about the refrain and configuration of notes that extend beyond a natural handspan is further explored in their discussions, reinforcing the idea that the piano plays a larger role in these individual researchers' lives, rather than just a mere interest in their experiment on SRFs. At least, this is my interpretation. But Cunningham et al. justify their research by suggesting, '[t]his paper describes the creation of a platform to investigate' cognitive embodiment.[1057] Three years later, in 2021, the SR3T developed by Cunningham et al. as a 'platform to investigate'[1058] cognitive embodiment, is used by Shaftil et al. to assess 'constraints of human augmentation' creating a 'new custom motor coordination assessment, the Human Augmentation Motor Coordination Assessment (HAMCA)' to verify the human motor control and neurocognitive adaption of the brain to new technologies seen in Figure 47.[1059]

[1054] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p669.
[1055] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p669.
[1056] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p669.
[1057] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p665.
[1058] Cunningham et al., "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks," p665.
[1059] Shafti et al., "Playing the piano with a robotic third thumb: assessing constraints of human augmentation," p1.

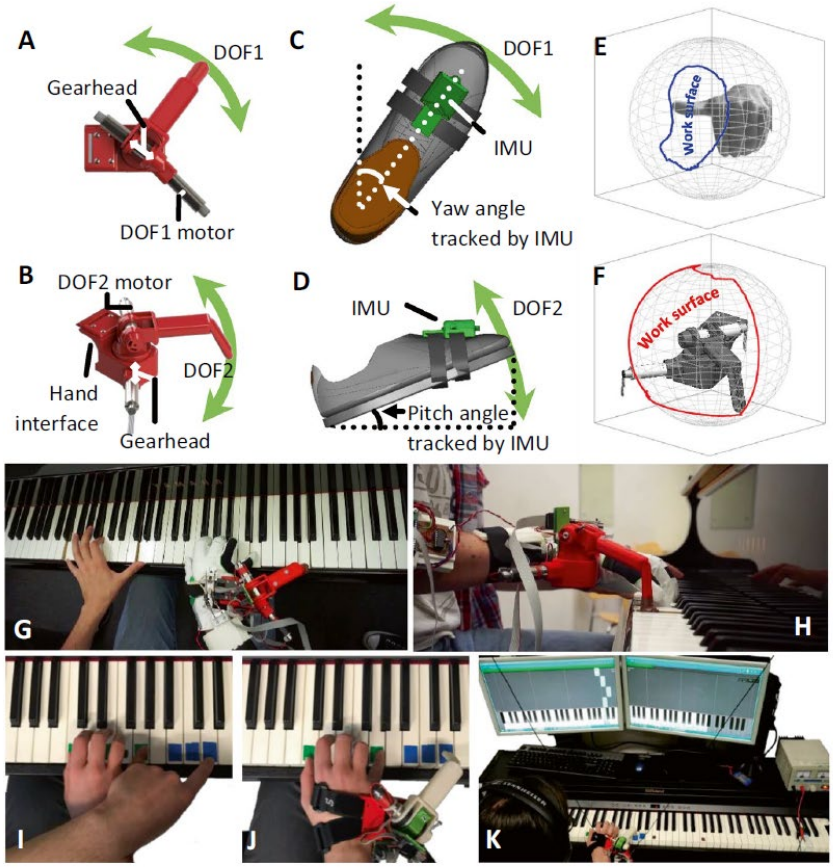

Figure 48 - Playing the piano with the Supernumerary Robotic 3rd Thumb (SR3T) taken from Shafti et al.[1060] Piano playing task setup. (A) Top view rendering of the SR3T, showing the horizontal motion DOF and relevant motor. (B) Side view rendering of the SR3T showing the vertical motion DOF and the relevant motor. (C) Top view rendering of the SR3T control interface for the 1st degree of freedom (DOF); the participant controls the motion of the SR3T using their right foot, captured through an inertial measurement unit (IMU) worn on the foot. (D) Side view rendering of the SR3T control interface for the 2nd DOF. (E) Work surface of a human thumb end-point projected on a sphere for comparison with (F) the work surface of the SR3T endpoint projected on a sphere—augmenting work surface range for the human (see methods). (G, H) Top and side view of the unconstrained pilot experiment: an experienced piano player freely improvising on the piano while wearing and making use of the SR3T, effectively playing 11-fingered piano within one hour of use. (I) Systematic experiments: playing the piano sequence using five fingers of the right hand plus the left-hand index finger (LHIF) and (J) Playing the sequence using the SR3T. (K) A participant plays the sequence of notes as displayed on the monitors in front of them, using the SR3T.

The unfortunate lack of insight from a subjective perspective is that these two projects are limited, moderated, and overlook the possible theoretical, artistic, and poetic scenarios that can emerge between the SR3T and the piano in music creation, which can transform individuals through augmentation. We can also position 'the lack' here, where researchers employ a form of self-prohibition in their pursuit of music passion, seeking to fulfil their desires through research by transforming their SR3T studies into scientifically traversable, reviewable, and useful content across various contexts. Both Cunningham et al. and Shafti et al. could have used the refrains using the

[1060] Shafti et al., "Playing the piano with a robotic third thumb: assessing constraints of human augmentation," p3 Figure 1.

eleven fingers (provided by the SR3T) to creatively explore the fertile dimensions of subjectivity and its neurocognitive impacts on augmentation and acceptance. Guattari would suggest this type of exploration of music is 'not the invention of a new medium of communication but the invention of a new kind of relation with what is communicated.'[1061] There is a lost opportunity for a more nuanced understanding of the brain's functions and the relationship between the SR3T and the psyche, as well as subjectivity, when examining augmentation that researchers have not yet explored. The cross-engagement of these areas, where individual researchers relate therapeutic and analytical processes arising from creativity and relational aspects to the collective unconscious, is a result of this type of techno-subjectivity (human-SR3T augmentation). This idea is expressed by Guattari when he suggests 'inventing a musical universe, a different relation with musical objects: music that comes from within and not from somewhere outside. In other words, what it is doing is inventing a new perception'.[1062] Guattari discusses the very foundational notions of how transversality in our environments can meld the relationships of inner creativity through an instrument that alters subjectivity. He reframes this idea this time, using the idea of technology when he declares, 'music and technology[…] we could also consider it as an invention of a different musical world and a different perception.'[1063]

The subject of the SR3T augmentation (the patient) can express pleasure and desire that can benefit them, leading to a deeper understanding of the individual and their relationship with the world. This complex array of technics and human interaction has life-giving, enriching and nourishing benefits for subjectivity. The prospect of augmenting oneself with a third-thumb can be further utilised in the analysis and comprehension of the intra-subjective and inter-subjective processes of society, as well as its intricate universal relations within its context, whether economic, political, or social. These dimensions are the minute scales described by Guattari that bring about change (molecular revolutions). Guattari suggests:

> The idea of molecular revolution concerns every level synchronically: infrapersonal (at work in dreaming, creation, etc.), personal (in relations of self-domination, what psychoanalysts call the superego), and interpersonal (in the invention of new forms of sociability in domestic, romantic, and professional life, and in relations with neighbors and school).[1064]

What is being described by Guattari is the global properties of pleasuring: the awareness, finding new sounds for sheer enjoyment, evaluating their affect on the mind and body, and 'articulate[ing]

[1061] Guattari, *Molecular Revolution in Brazil*, 1, p383.
[1062] Guattari, *Molecular Revolution in Brazil*, 1, p45.
[1063] Guattari, *Molecular Revolution in Brazil*, 1, p406.
[1064] Guattari, *Molecular Revolution in Brazil*, 1, p62-63.

alternative processes'[1065] and 'alternative formulas'[1066] for subjectivity.[1067] Yet, even with their shortcomings, these studies remain resourceful and unique because of their consideration and inclusion of such things as the piano as a site for exploring new possibilities. The studies show that groups with leading unconscious coefficients of transversality are opening their eyes to the possibilities of augmenting a third-thumb.

A critical aspect of the social relations displayed by most researchers on SRF is their tendency to focus on angles that cater to the commercial or scientific interests of industrial markets. Guattari suggests in his explanation of capital that the process that changes the revolutionary processes of subjectivity can be altered by changing our worldviews through music and the arts rather than capitulating to capitalistic subjectivity. Guattari suggests that '[r]evolutionary microprocesses [those leading to molecular revolutions of subjectivity] may not be of the same nature as social relations [those formed in dominant hegemonies]. For example, an individual's relation with music or painting can stimulate a totally new process of perception and sensibility',[1068] changing ideas and habits of relating globally to the world and opening the circumscribed relationships that involve them. The elucidation by Guattari references just one example of a small change that leads to immense shifts in one's relationship with the world through music, caused by opening the coefficient of transversality, which can turn around the vast ship of subjectivity as it has been described so far.

These two studies, which utilise the piano, do not employ the same institutionalised and scientific methods that other researchers use to test their SRFs. They employ more abstract and creative thinking, yet they also display a semblance of understanding of the users' and the researcher's desires when deciding to use the piano as a test bed for the SRF (or SR3T). Most researchers, if not all, use tests with equivalent repetition of grasping objects in their studies, which does not relate to the extensive set of actions the hand performs in activities of daily life (ADL). Nor do they consider the hand a site of pleasure or desire, while the hand has been the site for the considerable evolution of humanity, culture, arts, science, and technology. A demonstration of the examples of the type of standard single-handed tests activities using SRFs deployed to replicate ADL are things such as grasping a ball, holding a tablet, opening a can, opening a screw top bottle, opening a jar lid, lifting a

[1065] Guattari, *Molecular Revolution in Brazil*, 1, p132.
[1066] Guattari, *Molecular Revolution in Brazil*, 1, p211.
[1067] For Guattari the ‘alternate’ reference through his chapter section ‘Minority, marginality, autonomy, alternative’ is the possibility of subjectivity to be considered in beien developed outside modelled versions of the individual on the road to becoming faithful, singular, unique individuals or subjects. He mentions this in in Guattari, *Molecular Revolution in Brazil*, 1, p177.
[1068] Guattari, *Molecular Revolution in Brazil*, 1, p64.

bucket or opening a bag of crips, as examples[1069,1070,1071,1072,1073] seen in Figure 48 - Figure 52. Only one group, Hussain and Prattichizzio, presents the main category of human grips rather than individual types of grasps, such as the '*anatomically impossible* grasps' shown in Figure 52, which is the ulnar grasp. These natural human grips, including the power grip and precision grasp, have been key to the evolutionary epoch of human evolution and innovation, particularly in the use of tools and technology (discussed in Chapter 3 and Appendix 2, citing Napier). Yet Hussain and Prattichizzio still view their grasp in the context of very standard types of objects as the others.[1074] The view of researchers who duplicate grasping such a limited array of objects gives a very narrow impression of users' needs. By doing so, researchers show a lack of consideration of the user's real desires and their subjectivity in wanting to either have an extra thumb or replace a missing function of a finger(s). We can confidently say that those with lost hand function or those wishing to augment their healthy hands would need a proof of concept that is more considerate of the wide-ranging capabilities demonstrated by an SRF. Users would likely be looking to supplement their other desires that may be invested in augmentation. However, what is interesting about the images presented in Figure 48-Figure 52, which show the categories of grasps, is the lack of recognition of their significance for evolution, society, politics, and even their economic impacts. I am especially referring to the 'anatomically impossible grasps' shown in Figure 52. Suppose the hand can now do something it has never done before. In that case, this change presupposes a new type of relation between the subject and all objects in its environment, altering how we write, paint, play music, and how we configure our ideas of ourselves. Importantly, it also affects those ideas that connect us, including the other endeavours that encompass human creation.

[1069] Setiawan et al., "Grasp posture control of wearable extra robotic fingers with flex sensors based on neural network," p13-16.
[1070] Hussain et al., "Toward wearable supernumerary robotic fingers to compensate missing grasping abilities in hemiparetic upper limb," p11.
[1071] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p17.
[1072] Hussain et al., "Design and Prototype of Supernumerary Robotic Finger (SRF) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment," p403.
[1073] Hu, Leigh, and Maes, "Hand development kit: Soft robotic fingers as prosthetic augmentation of the hand," p27.
[1074] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, p112.

Figure 49- The soft sixth finger devised by Hussain et al., which tested its various grasp capabilities, was taken from Hussain et al.[1075] The soft sixth finger grasping various objects with different shapes and sizes: (a) tomato can, (b) chocolate pudding box, (c) chips can, (d) sugar box (e) mustard container, (f) gelatin box (g) coffee can (h) biscuit box (i) meat can. The device is intrinsically-compliant and adopts itself to the shape of the grasped object.

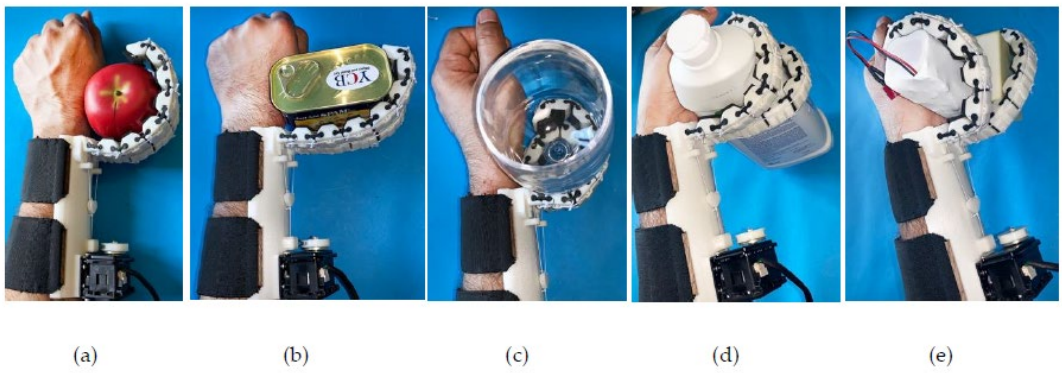

Figure 50 - The robotic extra finger tested for its various grasps taken from Malvezzi et al.[1076] Examples of grasps realized with the wearable device: (a) apple, (b) rectangular box, (c) glass, (d) bottle, (e) two different objects (battery packs).

[1075] Hussain et al., "Toward wearable supernumerary robotic fingers to compensate missing grasping abilities in hemiparetic upper limb," p11 Figure 10.
[1076] Malvezzi et al., "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation," p17 Figure 12.

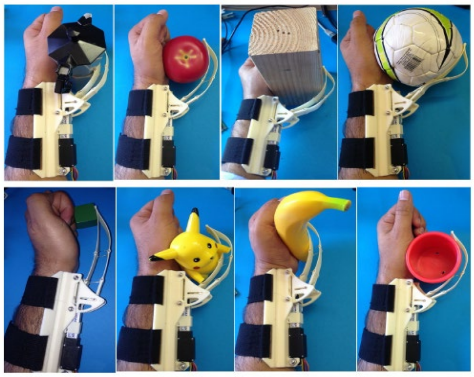

Figure 51 - The different Supernumerary Robotic Finger (SRF) grips inspired by the Fin Ray Effect taken from Hussain et al.[1077] Grasping experiments using different objects of various shapes and sizes.

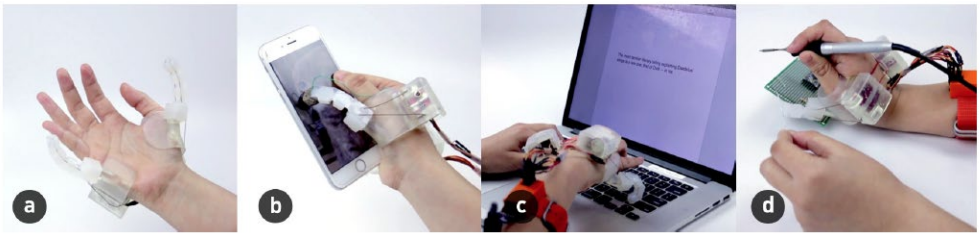

Figure 52 - The different grips of the Soft Robotic Fingers tested performing various tasks taken from Hu et al.[1078] a) The configuration of the system. b) performing multi-touch gesture with the soft robotic finger. c) the soft robotic finger supports keyboard typing. d) the fingers can hold and adjust the position of an object in tri-manual tasks.

Figure 53 - The various important types of grasps as defined by Hussain and Prattichizzo using the same standard objects taken from Hussain and Prattichizzo [1079]. Examples of possible achievable grasps at working positions (a–d) and bracelet at rest position (e). In a and b, the robotic finger coordinates with the healthy hand to realise the anatomically impossible and ulnar grasp, respectively. While in c and d it interacts with the paretic hand to realise power and precision grasp

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[1077] Hussain et al., "Design and Prototype of Supernumerary Robotic Finger (SRF) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment," p403 Figure 7.
[1078] Hu, Leigh, and Maes, "Hand development kit: Soft robotic fingers as prosthetic augmentation of the hand," p27 Figure 1.
[1079] Hussain and Prattichizzo, *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs*, p112 Figure 6.13.

Whether inspiration from nature has been applied in the Fin Ray Effect or to the Otariidae (eared) seal, there is a diversification in the understanding of how an SRF can be designed to meet the mechanical and ontological design challenges that seem to stymie researchers. The use of the piano as a test bed for testing neurocognitive augmentation of the SRF, even if it forgoes the opportunity to expand the test to an understanding of desire and subjectivity, remains an atypically inventive move in the field of SRF that represents the openness that works in the representation of unconscious coefficients of transversality. It can only be described as a Guattarian transversal relation of a desire for music, inspiring researchers to understand techno-subjectivities, even if it is still in the early stages of a *coefficient of transversality.*

The emergence of coefficients of transversality in the field of SRFs

Breaking new ground is not easy. It requires considerable energy to break habits, break barriers, and innovate. For the field of SRF to achieve this, researchers need to utilise Guattari's concept of a greater unconscious coefficient of transversality to make them proactive in seeking inspiration through a broader lens in their perspectives, as exemplified in this chapter. The search for inspiration addresses the problems of epistemology and the designs that inform them. In the previous chapter, I discussed Guattari's ideas of the subject groups, those with the means and power to instigate change and influence. We can consider these groups of researchers, who may be leaders in the field of SRF, who may also be under the structures of research institutions bound by Guattari's vertical and horizontal structures, to try to find the coefficients of transversality in their projects, emancipating themselves from the structures of their research teams and the commercial motivations for their projects. Diversity can be achieved, for example, by being more interdisciplinary, calling on wider research fields to support their work and working with new alliances. Following Guattari's ideas on transversality, there is a need to find alternate alliances, which Guattari suggests are essential to uncovering the true nature of the expression of desire such as those in the field of SRFs: '[t]he alliances, in this case, would be characterised by constituting systems of "transversality" whose criterion is the position of desire.'[1080]

These propositions for change in the SRF research field are akin to the opening of Guattari's transversal blinkers, allowing us to see the world from other perspectives. We see this in all three innovative projects described in this chapter. Be it the inventiveness of using the structures of the

[1080] Guattari, *Molecular Revolution in Brazil*, 1, p177.

fish fin to articulate a stronger, more reliable gripper for an SRF such as the one in the Fin Ray Effect project or the use of Origami and Kirigami art to cover the Otariidaes-inspired SRF or indeed the use of the piano as a way of understanding the neurological effects and augmentation capability of the SR3T. Such movements would see us on the road to increasing the unconscious coefficients of transversality in all spheres of life through their ripple effect across society. For example, reconfiguring the social dynamics of such research groups by placing the user at the centre of the research, rather than making them the 'end-user', would change the researcher's perspectives and contribute to a new dynamic in the design of SRFs. Guattari spoke about how the 'latent and repressed coefficient'[1081] is at the boundary between people at the coalface of subject and subjugated groups. Positioning the user and the researcher at the same level in the project hierarchy can allow 'transferences that have a therapeutic effect' to bring ideas from the unconscious and create space for their expression, as suggested by Guattari.[1082] We can think of the interaction between the user and the researchers as an instance in which this therapeutic transference can be conveyed in the discourses on SRFs. Placing the user at the forefront of the researcher's focus will involve the user in producing these SRFs, oriented towards designing for desire, within the context of an environment that uncovers the unconscious pleasures of augmentation. This is similar to Guattari's example of La Board, where he stated that the coefficient of transversality was greatest when patients were allowed to interface with nurses who were best placed to understand and derive therapeutic benefits for the patients,[1083] given that the nurses had more genuine relationships with one another. The comparison here would be that users who need/want the SRF have more at stake in open relationships with one another. Thus, they can influence change given their distance from the research hierarchies, both social and professional structures that control research protocols. Such acts that involve transversality mean that innovative solutions arising from transversality can address current problems.

It is also part of Guattari's prescription for transversality to open the floodgates to the regime of signs and signifiers so they can unfastened ideas from their habitual references and put them at the feet of diverse readings, rather than their prescribed habitual interpretation at the risk of group fantasies of subject groups, and their institutions that give rise to them (not to mention their Freudian and Lacanian ideals).[1084] In the discourse on SRF, a specific type of signification operates in the depiction and discussion of the concept of a third-thumb, where the prosthetic is a practical tool rather than a radical one. This view conveys a diminished perception of a project that could

[1081] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, 9113.
[1082] Guattari, *Molecular revolution : psychiatry and politics*, p18.
[1083] Guattari, *Molecular revolution : psychiatry and politics*, p18.
[1084] Guattari, *Molecular revolution : psychiatry and politics*, p22.

otherwise be interpreted as representing an object of desire at a level that expresses the unconscious need for augmentation and reveals its true meaning in terms of subjectivity and the body. Rather than merely thinking of a prosthetic to replace a lost functional use of a limb/appendage or to enhance the factory worker (to make them more efficient), we can reframe the signifiers formed in the habitual context, changing their effects into affects for subjectivity. An example is the musicality of the piano, which utilises a hand-SRF machine in the context of art or literature, altering the social context and significantly affecting and shaping the subject's sensibilities. These are but a few avenues that Guattari has laid before us in pursuing a project of this type of combined techno-subjectivity (alternations of subjectivity via technics of augmentation) that peers into our futures in which we reframe individual and societal relations through the third-thumb. Let all, including artists, theorists, and others, be involved in a collaborative project for which an SRF or a third-thumb can be used as a tool that reconfigures the body. Let it be a tool for social experimentation to alter subjectivity to advance the projects that can dismantle the horizontality and verticality that separate the individual from the collective.

We should consider the broader range of signifiers of creativity (beyond serialised significations tied to transference and the Oedipal Complex) that can be uncovered through unexpected associations, such as those found in dreams or creative pursuits. In this chapter, I explored how Guattari's proposed ideas can enhance our broader interpretation of the signifiers of SRF or a third-thumb, allowing them to be analysed as latencies of translation of other social and societal issues related to diversity and equity in an era of relations mediated by technological evolution. The formation of techno-subjectivities, as undergirded by the ideas of Guattari and transversality, would prompt researchers to think more creatively about subjectivity and the instances of desire that surround the field of SRF, including the virtues of augmenting a third-thumb to the body and its resultant shift in subjectivity. Researchers would benefit from considering the third-thumb as an object of desire rather than the social and political expansion of capital markets, outside the power discourse of a commercialised robotic finger as a technological forerunner that brings prestige, superiority or even serves as a tool for increased production or a means for the privileged classes.

The field of SRF would greatly benefit from its subject groups, particularly those with increased coefficients of transversality, leading to diversified ways of being open to transversal behaviours that can help resolve technical and epistemological problems. Based on Guattari's insights that have been so far presented on the power of incumbency in subject groups for change, which translated to their ability to engender and influence change by spreading coefficients of transversality into society, institutions and groups such as those who develop SRFs would make a greater contribution to science and society in their research by uncovering and paving the road for our futures. The opening

of the blinkers that Guattari refers to will allow light into the dark recesses of hidden power structures of signification, banishing the mechanisms of groups' fantasies. This may involve relinquishing ideas of archaic scientific methods that excluded the 'end-user' and entering into a field of co-design. Guattari warns us that in an effort to defeat hierarchies of verticality and enslavement embedded in horizontality, one must be careful not to subscribe to the counterfeit ideals that come from 'mythology of "togetherness"'[1085]. With Guattarian horizons on subjectivity, one must form one's relationship with the group, banishing the castration complex and the terror of Oedipus to overcome servitude to the mendacious archaic psychoanalytical ideal that has done such a disservice to society. Guattari suggests this in the following passage, where je suggests we must form interconnected networks:

> caught up in the existence of the other, who alone guarantees what reaches me via human speech. Unlike what happens in individual analysis, there is no longer any imaginary reference to the master/slave relationship and it therefore seems to me to represent a possible way of overcoming the castration complex.[1086]

The keen-sighted Guattarian ideas can help give perspective to researchers in the field of SRF, enabling them to escape from their master-slave relationships that include being bound to their citations, reviewers, superiors, and institutional directives, which may prohibit researchers from pursuing collective desires. And pursue this activity through human speech, discussed in Chapter 2, 4A, 4B, as part of the assemblages of enunciation. This proposed change by Guattari may become the transversal vector that breaks with the structures that preclude any diversion from normativity. Guattari's ideas give us the confidence to be permitted and not afraid to try new things, speculate, and diversify different ideals on the road to creating a third-thumb. Guattari's ideals help shape the ways that group analytic processes and those that bring forward the unconscious coefficients of transversality in the field of SRF motivate the realisation of the unimagined dreams of collectives and individuals in the creation of SRFs. I would suggest that Guattari would incorporate users' dreams into this movement. It would be a collective attempt at co-design within a context of creating radical projects emboldened by unconscious coefficients of transversality in groups that allow them to escape the punitive social pressure of transference and the castration complex.[1087]

[1085] Guattari, *Molecular revolution : psychiatry and politics*, p21.
[1086] Guattari, *Molecular revolution : psychiatry and politics*, p22.
[1087] Guattari, *Molecular revolution : psychiatry and politics*, p22.

Conclusion

Guattari gives us insight into what he regards as the 'organogramme of a pyramidal structure'[1088] that marks his ideas on the verticality of hierarchies found in modern-day capitalistic societies, together with his ideas on the dispossessed subjectivities trapped in the horizontal structure of powerlessness of these regimes. He provides an example via the concept of systems of capture, illustrating capital's hold on desire and the infrastructure complex that insistsently regulates the semiotics machines that utilise signifiers to capture the ego, such as the Oedipal and castration complexes. The subject is thus perpetually entrenched in a system of hierarchies that isolates individuals from one another. The systems of subjective capture described in these cases cause Guattari to refer to Marxist failures, specifically the loss of the revolutionary potential of workers, who are robbed by those at the top of the pyramidal structures. According to Guattari, these workers have become subject to a system of guarantees that ensure they remain acquiescent and unable to affect their destinies. Guattari suggests that it only takes power within the subject groups that contain the coefficients of transversality to mediate, influence, and affect change through the smallest reorientations of subjectivity. The ability to affect change provides a rationale for viewing innovative projects in the field of SRFs as transversal, aligning with Guattari's examples and explanations, such as the impact of music on affects and the alteration of subjectivities. To draw inspiration from the most transversal universes of ideas, research teams such as the Fin Ray Effect project, the Otariidae-inspired SRF project, and the SR3T project, which uses the piano as its test bed, are demonstrating high unconscious coefficients of transversality. I propose that their endeavours advance usability inspired by their social and cultural insights, including their personal desires and their acute understanding of relationships with context, as proof of an opening of the coefficient of transversality. This building on such unexplored territories is the type of multivalent, cross-pollination set of alliances that is so characteristic of vectors of transversality that sweep the unconscious desire and collective imaginations that Guattari backgrounds together with his oneiric exposition of subjective insights: 'our own dream when we wake up (in a kind of self-analysis), a poetic production, or any kind of creative production' affects our understanding of subjectivity.[1089] Guattari reminds us that identifying the sources of transversality and its unconscious coefficients isn't easy because the 'source of power'[1090] is not obvious, yet once set into action, transversality can easily be distinguished for its micropolitical revolutionary power.

[1088] Guattari, *Molecular revolution : psychiatry and politics*, p17.
[1089] Guattari, *Molecular Revolution in Brazil*, 1, p346.
[1090] Guattari, *Molecular revolution : psychiatry and politics*, p19.

Chapter 4E - Desire to augment via transitional objects of transversality using Danielle (Dani) Clode's Third Thumb project

Introduction

This dissertation aims to bring together a Guattarian and Rolnikian understanding of subjectivity and the field of the SRF. The following chapter, in the same vein as previous chapters, explores each theoretical, conceptual quality and technological particularity. This is the last in the series of five chapters and, crucially, builds upon the previous sub-thematics examined in Chapters 4A, 4B, 4C, and 4D, bringing into focus how object theory and desire function as messaging systems to create a new type of society—one defined by what Guattari terms a *new smoothness* for subjectivity. To demonstrate how this transformed society might manifest, I analyse exceptional projects that illustrate transversal subjectivity in action, with their remarkable insights into how Supernumerary Robotic Finger (SRF) or third-thumb augmentation can transform people, economies of desire, and social structures. These augmentations serve as concrete examples of how machinic heterogenesis (discussed in 4B) operates not merely at a theoretical level but through embodied experiences that reconfigure our relationship to the technics of augmentation, corporeality, and collective becoming.

I shall engage Danielle Clode's Third Thumb (proprietry name) artifact to explicate the forays of how her very innovative approach to SRF design in her prosthetic designs as an instance of an object of desire and a transitional object of transversal mobilisation of ideas that enables Guattari's new smoothness in constructing a new order with refreshed, inclusive, interconnected, intersocial, political equitable, dogmatically free and economically unbondaged values.

Objects and relations

Guattari uses objects to reference and frame the relationships to and between a range of entities, including persons, things, groups, institutions and all other structures, including psychological, socio-political and economic structures. We often say they are an object of my affections. In Guattari's case, the object is the affection itself. This is useful for understanding the analytic system that is part of the processes of transversality, where the object is set free and in line with desire. Guattari states there are numerous ways in which an individual forms their subjectivity, which have evolved through

different philosophical and psychological frameworks.[1091] To this effect, Guattari references René Descartes' concept of the self and thought, Immanuel Kant's ideas on morality, the open idea of nature and the environment and our relationship to it, and, importantly, the idea of our relationship with others through the conception of object theory (the way individuals perceive and relate to other people, treating them as objects in their social and psychological frameworks).[1092]

In this context, object theory and its related theories, including *partial objects*, *object petit a*, and *transitional objects,* are important points for analysis in transference and relationships between the inner self, outer self, and reality, as well as understanding how they relate to investments in desire and ultimately how they are transformed by transversality. Guattari thus suggests:

> it was necessary to provide other foundations to the subject and his relations: the relation of the subject with thought (the Cartesian cogito), with moral law (the Kantian numen), with nature (a different way of feeling it and conceiving it), with others (the conception of the others as object).[1093]

Guattari uses Freud's concept of partial objects 'breast, feces, penis, and so on at the heart of psychic operation'.[1094] And even Lacanian ideas of the object that is reduced to a matheme, in addition to his preference for transitional objects[1095] for their 'analytical power'[1096] to interpret the dynamics of the unconscious in the social field in relation to groups and institutions,[1097] whilst in flight between subject and subject. Partial and transitional objects can be used to analyse the process that gives meaning to various types of transferential phenomena. This involves using signifiers within their context to decipher their semiotic valences during the transfer of the partial object or, simply, in the projection of that object onto the dynamics of the relationship. For example, a particular attachment to an object in childhood will be seen in that person's personality traits in adulthood, which inspire feelings that help attachment. Guattari explains to his readers as an important idea: '[t]he important thing here is to get to the remarkable message, as well as to the object-carrier and founder of the message.'[1098]

Partial objects are conceptualised in psychoanalysis as specific aspects of the self or others that become invested with intense emotional significance. They are part of us and part not of us. These partial objects can be things like body parts that hold particular meaning for the individual, such as

[1091] Guattari, *Molecular Revolution in Brazil*, 1, p50.
[1092] Guattari, *Molecular Revolution in Brazil*, 1, p50.
[1093] Guattari, *Molecular Revolution in Brazil*, 1, p50.
[1094] Guattari, *Molecular Revolution in Brazil*, 1, p399.
[1095] Guattari, *Molecular Revolution in Brazil*, 1, p92,p467.
[1096] Guattari, *Molecular Revolution in Brazil*, 1, p385.
[1097] Guattari, *Molecular Revolution in Brazil*, 1, p399.
[1098] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p81.

the penis or the breast, that become significant in the psychic structure during development. These partial objects have advanced emotional investment for the subject (the child). These objects are associated with pleasure and desire as development progresses into adulthood. Partial objects are components within the psyche that represent fragmented parts of the self. They are internal, psychological entities that psychoanalysis often deals with, particularly in understanding complex mental states and processes. In Lacanian terms, these partial objects serve as precursors to the *object petit a*. The object petit a is the unattainable object of desire, a fantasy. Unlike partial objects, the Lacanian objet petit a operates on a symbolic level.[1099] The object petit a represents an elusive object of desire that plays a crucial role in the organisation of subjectivity and drives behaviour.

More importantly, Guattari focuses on Donald Winnicott's theory of transitional objects as the primary transferential means of communication, often manifesting in childhood through toys and comfort items that children use to facilitate the transition from dependence to independence. These objects represent both emotional and symbolic bridges between the child's inner world and external realities, which means that they are used by individuals (often children) to transition from a self-centred stage to one that includes others. These objects help develop self-other or, as Winnicott puts it, 'Not-Me Possession'[1100] , which facilitates differentiation, and plays a crucial role in early emotional development. For Guattari, the preference is to use transitional objects, objects that work in the space between the subject and 'the object as "not-me"'[1101]. Winnicott's *not-me* transitional objects become the operative systems that exceed their early childhood developmental context, used by Guattari as a running social, economic, and political analytical tool, projected by groups and institutions with a lasting relational connection to the psyche in subjectivities.

These concepts—object relations theory, partial objects, object petit a, and transitional objects—offer insights into how individuals form relationships and navigate desires and conflicts in the transferential phenomenon. They lead to the development of the sense of self and others within the context of psychoanalytic theory.[1102] This becomes especially important when we consider the body in relation to subjectivity and how its parts are projected during development in a manner that

[1099] Guattari, *Molecular Revolution in Brazil*, 1, p467.
[1100] Donald W. Winnicott, "Transitional Objects and Transitional Phenomena: A Study of the First Not-Me Possession1," in *The Collected Works of D. W. Winnicott: Volume 4, 1952-1955*, ed. Lesley Caldwell and Helen Taylor Robinson (Oxford University Press, 2016), p1.
[1101] Winnicott, "Transitional Objects and Transitional Phenomena: A Study of the First Not-Me Possession1," p1.
[1102] Guattari, *Molecular Revolution in Brazil*, 1, p305-06.

references various relationships. Guattari even says 'foundations to the subject and his relations […] with others (the conception of the other as object)'[1103] is part of the processes of subjectivation.

From this point of understanding relationships by targeting the use of objects, Guattari employed the concept of institutional objects as entities that represent the formation of relationships and their meanings within the psyche of object-oriented relational constituents. These include elements within institutions that shape and regulate individual and collective behaviours, thoughts, and interactions. Examples of these were given in Chapter 4B & D on groups and institutions, which include standards, norms, roles, practices, hierarchies, and rituals that govern institutional life. These encompass governmental institutions, universities, political institutions, and mental institutions.

Given his open determinations about subjectivity, Guattari also references all types of objects that challenge traditional notions of identity by emphasising the fluid, complex, and interconnected nature of subjectivity, founded in Winnicott's transitional objects. He suggests that many internal and external factors shape subjectivity and calls for a broader, more inclusive understanding of what constitutes the self and how it is formed and transformed through object relations. He presents it in the following manner, warning us of the pitfalls of relying exclusively on partial objects, which are heavily relied upon in traditional approaches to forms of psychoanalysis. Guattari suggests:

> Hence, what we need to ask ourselves is whether we are going to be content with making the notion of identity explode inward—making it implode toward the theory of "partial objects"—or whether we are also going to try to make it explode outward, toward things such as Winnicott's "transitional objects," or institutional objects, toward any economic object, any machinic object that inhabits the social field.[1104]

We have previously discussed Rolnik and Guattari's ideas on machinic systems (Chapter 4B), which are sources of connectivity, stemming from the concept of desiring-machines and their role in assemblages. Expanding the idea to objects also confers their characteristics as objects within the economic system that hold value and meaning. They influence social relations and individual behaviour through their economic significance or signifiers.[1105] We can consider aspects such as the type of car one drives and its associated economic signifiers and symbolic representation. Transversality brings complex configurations of heterogeneous elements (objects, bodies, expressions, actions, cars) into assemblages that produce specific effects and diverse sets of subjectivity. Objects within these assemblages can be both material and immaterial, tangible and

[1103] Guattari, *Molecular Revolution in Brazil*, 1, p50.
[1104] Guattari, *Molecular Revolution in Brazil*, 1, p92.
[1105] Guattari, *Molecular Revolution in Brazil*, 1, p92.

intangible, and they are the connections between constituents or elements of the assemblages.[1106] Instead of being alienating forces embedded in partial object analysis, transitional objects can be used to expand our connections to various interpersonal references.

Assemblages of objects

Guattari's preference is for the broadest set of analytical apparatus, extending beyond the traditional psychoanalytical framework, which encompasses the scope of social, political, and economic elements within the collective facility of assemblages in the production of subjectivity.

Guattari's ideas move the purview of object theory beyond the bounds of intrapersonal, that is, beyond the persons' internal processes, to the interpersonal and into the broader social setting of groups and institutions that are heavily involved in the formation of subjectivity. Understanding the operation of object dynamics through transference leads to a better understanding of their social and institutional effects when considering transversality. Guattari's notions on object theory help extend transversality as part of the extended functions of analysis (schizoanalysis discussed in Chapter 4A), which Guattari attempts to impart when considering the impact of various environmental processes arising from social, economic, and political contexts that influence the production of subjectivity.

The new smoothness that comes in the wake of transversality

According to Guattari, 'The new smoothness corresponds, […], to new coefficients of transversality, to the invention of new constellations of the universe (becoming-woman, becoming-music, etc.)'[1107] When Guattari speaks of a 'new smoothness'[1108] that comes in the wake of transversality and its revolution, he refers to the invention of societies with rehabilitated social orders, thereby averting the directions of 'phallocratic, competitive, brutal values'[1109] of past systems. I would suggest that this new smoothness also encapsulates the potential for assembling objects, a diverse set of partial objects, transitional objects, institutional objects, and so on, in smoother and more seamless ways.

[1106] Smith, *Tranvsersailty Lecture 10*.
[1107] Guattari, *Molecular Revolution in Brazil*, 1, p417.
[1108] Guattari, *Molecular Revolution in Brazil*, 1, p416.
[1109] Guattari, *Molecular Revolution in Brazil*, 1, p416.

Let me briefly retrace some of the ideas discussed in the previous chapters that bring us to the point of 'new smoothness' outlined in Guattari and Rolnik's book, *Molecular Revolution in Brazil.* Guattari speaks of the engagement of the '*marginati*'[1110] or the socially marginalised, the minoritarian, and the non-guaranteed class - contributing to open possibilities for expressing their subjectivities or styles of living. We might understand their subjectivities through their cultural relations to transitional objects. We gave both economic examples and examples of altered subjectivities whose relations are transformed through this type of transversal engagement (in previous chapters). We also introduced Guattari's concept of the *coefficient of unconscious transversality* (in Chapter 4D). I noted the 'coefficient of transversality'[1111] to be understood as an indicator of a spectrum of blindness that recapitulates the degree of rejection towards others, a type of degree of blindness to opportunities to see others and to value them for their difference. This can also be seen in relation to the formation of the child's cathected relationship with transitional objects, which take on a new meaning within a broader set of relations.

In his book *Molecular Revolution Psychiatry and Politics,* Guattari says, '[i]n a hospital, the "coefficient of transversality" is the degree of blindness of each of the people present.'[1112] Also, in a previous chapter, I introduced Guattari's idea of subject-groups and subjected groups that can be the providers of the project of coefficients of unconscious transversality at the heart of open societies by opening their blinkers to *see* others. I discussed Guattari's ideas on the real manifest power for change that operates between independent groups (subject-group) and their ability to effect change in dependent groups (subjugated groups), respectively, tends to lie on the side of the subject-group's ability to influence the unconscious coefficients of transversality because of their internal power to negotiate with the ego. Again, we can liken this to the transition of the child from the mother to the transitional object that allows the child to separate and grow. As Guattari has suggested, subject groups are the analytical purveyors of their destiny, death and finality. They tend to have a logical understanding of life's limitations and the dynamics of its consequences. However, it is not always easy to identify who or which subject group has the power to wield transversality, says Guattari:[1113] 'In fact, the level of transversality existing in the group that has the real power unconsciously determines how the extensive possibilities of other levels of transversality are regulated'.[1114] This is part of the illusory nature of partial objects that allows the child to develop transitional relations with the world. Subjects with this unconscious level of transversality are the

[1110] Guattari, *Molecular Revolution in Brazil*, 1, p416.
[1111] Guattari, *Molecular Revolution in Brazil*, 1, p417.
[1112] Guattari, *Molecular revolution : psychiatry and politics*, p18.
[1113] Guattari, *Molecular revolution : psychiatry and politics*, p19.
[1114] Guattari, *Molecular revolution : psychiatry and politics*, p18.

ones who exert power intrinsically and are the instigators of dialogue for analysis. I would suggest that they lead to positive transitional relationships, which help build an understanding of the world around us. More often than not, the subject-group with this power must make a concerted effort to engage and influence other groups through dialogue and a high level of openness to thought, unlocking their creativity. In his example of hospitals, Guattari explains that different groups are imbued with different coefficients of transversality, but it is at the level of the interface with the patients where the coefficient of transversality is at its highest – this is because it is the point at which the 'patients can make transferences that have a therapeutic effect.'[1115] The creation of a transitional object included the transference into a world of art and creativity, as described by Winnicott himself.[1116] According to Guattari, the analysis and examination of the self are at their peak productivity when transference is most meaningful in institutions. I would suggest that the messaging processes in forming and expressing transitional phenomena be at their liveliest. Guattari says, '[i]f a certain degree of transversality becomes solidly established in an institution, a new kind of dialogue can begin in the group'[1117].

Coefficients of transversality may not always be heterogeneous in nature, warns Guattari. We can also suppose that in this process, the transitional phenomenon would become broken down and fail in its 'illusion and dissolution'.[1118] Guattari observed organisations and institutions that experience transversal inertia. In a heterogeneous mixture with elements that maintain their particularity and resist change, the mixture becomes subdued or subjected to a total (i.e., homogeneous) change. It may be possible, after all, for an institution to have different levels of intensity in its coefficient of transversality and still all 'remain homogeneous.'[1119] Therefore, Guattari tells us that the power that manifests in the most effectual strata or group 'determines how the extensive possibilities of other levels of transversality are regulated'.[1120] Where homogeneity might be thought of as the totalisation of objects under a single law (or name, or 'totem'), a higher coefficient of transversality equates to heterogeneous elements having the capacity to leave one group and enter another - to connect in new ways, as do transitional objects.[1121]

[1115] Guattari, *Molecular revolution : psychiatry and politics*, p18.
[1116] Winnicott, "Transitional Objects and Transitional Phenomena: A Study of the First Not-Me Possession1," p13.
[1117] Guattari, *Molecular revolution : psychiatry and politics*, p20.
[1118] Winnicott, "Transitional Objects and Transitional Phenomena: A Study of the First Not-Me Possession1," p9.
[1119] Guattari, *Molecular revolution : psychiatry and politics*, p18.
[1120] Guattari, *Molecular revolution : psychiatry and politics*, p18.
[1121] Smith, *Tranvsersailty Lecture 10*.

Guattari suggests that transversality in groups acts as a mirror, and when the individual sees his own reflection analysed, his own neurosis, 'he will be revealed to himself'. [1122] Accordingly, he says, when transversality is established in the therapeutic institution, a new type of dialogue begins, and that comes from an 'abolition of hierarchical privilege' starting with the 'doctor who abandons his phantasy status to place his role on a symbolic plane' leading to a delegation of power and divesting his roles and responsibilities.[1123] He breaks his role into fragments that can be analysed and provide symbolic meanings that are easier to interpret. As Guattari says, splitting up the doctor's roles (the object) and responsibility carries with it the transference of the partial objects or transitional objects (subjective objects of the patient's impasses), allowing them to be viewed in new ways and leading to transversal analysis. Guattari explains this in this way:

> The object of that function moves away from "totemization" and is transferred to different kinds of institutions, extensions and delegations of power. The very fact that the doctor could adopt such a splitting-up would thus represent the first phase of setting up a structure of transversality.

Hence, this transformative power of transversality and transitional objects leads to new spaces within institutions and new ways of investing in society, one that is not based on capital. Guattari speaks of a world where transversality reunites 'inventions [of a world] of different relation[s]'[1124]. He says, '[t]he new smoothness corresponds, on the contrary, to new coefficients of transversality, to the invention of new constellations of the universe (becoming-woman, becoming-music, etc.)'[1125]. Guattari's new smoothness refers to emerging forms of smooth territories in contemporary society, which arise in response to or alongside the highly structured and regulated spaces typical of modern life.[1126] This new smoothness can be seen in digital and virtual environments, where traditional physical boundaries and structures are less relevant, and interactions are more fluid and decentralised. In essence, Guattari's new smoothness captures the evolving nature of spaces and social arrangements in a world increasingly influenced by technics and changing forms of communication and interaction. It represents a shift towards more open, flexible, and interconnected modes of existence, challenging the rigid structures of traditional societal frameworks. Guattari suggests:

> The question of the assemblage of expression, of machinic assemblage—which changes the data, which reworks it, which drives forward new references, new universes—is inseparable from the question of the territories or the "bodies without organs" on which the machinic becomings, the

[1122] Guattari, *Molecular revolution : psychiatry and politics*, p20.
[1123] Guattari, *Molecular revolution : psychiatry and politics*, p21.
[1124] Guattari, *Molecular Revolution in Brazil*, 1, p416.
[1125] Guattari, *Molecular Revolution in Brazil*, 1, p417.
[1126] Guattari, *Molecular Revolution in Brazil*, 1, p413.

> incorporeal processes, are inscribed, marked, and embodied. But it's precisely here that we find all this ambiguity of territory, of deterritorialization and reterritorializations.[1127]

Guattari conveys the idea that for a change in subjectivity 'which changes the data' of the individual, we must connect to all territories of understanding across all 'incorporeal processes', meaning all possible systems of expression, including our acceptance of the non-human properties of our context, both existential and real. Only then do we reach the 'ambiguity of territory' that can engulf and prompt reconsideration. Such an 'ambiguity of territory' would lead toward the 'new smoothness'. It involves the reinstatement of relations with the other through a shift in understanding how we form relationships through transitional objects of desire. From there, we arrive at this new smoothness. By referring to Guattari's full quote on the new smoothness, we can understand from his example how the new smoothness relates to the body. In the example below, Guattari places the body on a level of all biological systems (not above), where the human body is part of another non-anthropomorphic process. Guattari proposes:

> The "new smoothness" is part of this theme that we are constantly discussing, which is that of the invention of a different relation—with the body, for example—a relation that is present in becoming-animal.[1128]

Becoming thus becomes an in-between state (a transitional object) on the road to an expansive possibility in our translations of meaning, initiated through transitional objects that can reshape realities, our experiences, and our dreams. Let's consider augmentation with an SRF as a transitional object that frees us from the grid of habitual social, political, and economic subjectivity (which Guattari warns is part of the process of capitalistic subjectivation). The SRF is a new concept in our relationship with the body, encompassing the structures that frame and contain it. Using the transitional object of the SRF as a stepping stone to a new smoothness, we are opening our subjective development to the various unexplored options in ways of *being* and *becoming*. We can then invoke a similar analogy where we become machinic ('great machines for struggle'[1129]) and transversal by augmenting with a robotic third-thumb, whereby the machinic becomes the vehicle of new connections for the transitional object, becoming something other than old wonted ways of perceiving and experiencing, and ultimately changing the dynamics of body relations. These new ways of altering subjectivity impact relationships, including how we interact with one another, with

[1127] Guattari, *Molecular Revolution in Brazil*, 1, p415.
[1128] Guattari, *Molecular Revolution in Brazil*, 1, p416.
[1129] Guattari, *Molecular Revolution in Brazil*, 1, p210.

other objects, with nature, and with the institutions that shape our lives and their various political structures.

Rolnik also speaks in unison with Guattari of a world of subjectivation, where subjectivity evolves through a process of 'becoming'.[1130, 1131] This becoming (transitional object), which can be thought of as a sef-actualisation of subjectivity (*becoming singularized*), manifests in connection with collective groupings in which we find our singular freedom to live and express our uniqueness in an autonomous relationship to our context. Singularization is the rise of the 'molecular dimension'[1132] of becoming that is arrived at through the presupposition of transversality in a state of autonomy. Guattari defines singularity (also discussed in Chapter 2) as 'a way of rejecting all these modes of preestablished encoding, all these modes of manipulation and remote control, rejecting them to construct modes of sensibility, modes of relation with the other, modes of production, modes of creativity that produce a singular subjectivity.'[1133] This is part of the new smoothness that precedes free-flowing subjectivity. For Guattari autonomy 'can bring together so many different levels of social life' in which its function or its 'functional autonomy' may initially serve as a functional response to resist, and is axiomatic of a struggle.[1134] Still, it becomes 'expressed at a micropolitical level—precisely that of the production of subjectivity'.[1135] This means that even though a singular subjectivity or autonomy initially focuses on a general vector of freedom, it ultimately translates into a microrevolutionary force of subjectivity, encompassing all subjectivities that connect to that struggle.

In this process, Guattari and Rolnik hope for countless small revolutions, based on this functional autonomy, to take hold. This snowball of subjective revolutions forms the basis of their book, *Molecular Revolution in Brazil*, and is part of their program of understanding and working with various minoritarian political and social groups that Rolnik and Guattari encounter during their tour of Brazil.[1136] In his travels with Rolnik, Guattari cites the struggles of Brazilian minoritarians and the marginalised in becoming—the process of emancipation, self-identification, and the project of actualisation. At the same time, Rolnik calls this a project of 'becoming-woman, becoming-plant, a becoming-animal, becoming-cosmos'.[1137] Indeed, as Guattari explains, the new smoothness is a

[1130] Guattari, *Molecular Revolution in Brazil*, 1, p395.
[1131] Guattari, *Molecular Revolution in Brazil*, 1, p453,63-67.
[1132] Guattari, *Molecular Revolution in Brazil*, 1, p103.
[1133] Guattari, *Molecular Revolution in Brazil*, 1, p23.
[1134] Guattari, *Molecular Revolution in Brazil*, 1, p74.
[1135] Guattari, *Molecular Revolution in Brazil*, 1, p74.
[1136] Chapters 1-3 outlining Chapter 1 'Culture: A Reactionary Concept', Chp 2 'Subjectivity and History', Chp 3 'Politics' in Guattari, *Molecular Revolution in Brazil*, 1, p21-179.
[1137] Guattari, *Molecular Revolution in Brazil*, 1, p416.

process in which subjectivity is not limited to humans. Rolnik speaks of the new smoothness as one that is inherent in the process of life, for all subjects of all kinds express innate desires to be and be transformed. For Rolnik, transversality is a form of deterritorialisation from the habitual, looking outward and becoming 'finely tuned'[1138] to the resonances and commonality between life elements. Rolnik suggests this eloquently: 'The desire for this autonomy of flight, where one would open up to the otherness of the world, allowing the affects mobilized by this openness to deterritorialize us.'[1139] She means that the preestablished sense of transversality, once initiated, leaves us voluptuously open to all possibilities and all alliances found in our relationships with others. Guattari and Rolnik's concept of new smoothness is their nirvana, where transversality brings us closer to ourselves and others through the functional autonomy of struggle for freedom, thereby fostering thriving subjectivities.

Danielle (Dani) Clode's Third Thumb prosthetic

One of the most interesting SRF research papers in the literature discussed in Chapter 3 was a paper titled 'Robotic hand augmentation drives changes in neural body representation':[1140] a collaboration between Tamar Makin and Danielle Clode at the University College London under the auspices of the *Plasticity Lab*. Clode, an artist at the Royal College of the Arts, inspired neurocognitive researchers like Professor Makin and those working at the *Plasticity Lab* to collaborate on this project using Clode's Third Thumb (name given by Claude to her SRF) to investigate the neurocognitive impact of having an extra thumb.[1141,1142] Clode's Third Thumb design has been described as an:

> award-winning graduate project at the Royal College of Art, seeking to reframe the way we view prosthetics, from replacing a lost function, to an extension of the human body.''Professor Makin (UCL Institute of Cognitive Neuroscience), lead author of the study, said: "Body augmentation is a growing field aimed at extending our physical abilities, yet we lack a clear understanding of how our brains can adapt to it. By studying people using Dani's cleverly-designed Third Thumb, we sought to answer key

[1138] Guattari, *Molecular Revolution in Brazil*, 1, p423.
[1139] Guattari, *Molecular Revolution in Brazil*, 1, p426.
[1140] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation."
[1141] "Robotic 'Third Thumb' use can alter brain representation of the hand," University College London, 2021, 2022, https://www.ucl.ac.uk/news/2021/may/robotic-third-thumb-use-can-alter-brain-representation-hand.
[1142] Chris Lane, "Robotic 'Third Thumb' use can alter brain representation of the hand," *UCL News* (https://www.ucl.ac.uk/news/2021/may) 2024, https://www.ucl.ac.uk/news/2021/may/robotic-third-thumb-use-can-alter-brain-representation-hand.

> questions around whether the human brain can support an extra body part, and how the technology might impact our brain.[1143]

The study looked at the implications of 'successful motor augmentation' on the 'neural representation and function' of the hand within the brain using 'functional magnetic resonance imaging (fMRI) to compare neural hand representation before and after Thumb use'.[1144] The hand has a well-established functional representation in the brain, located in the premotor, parietal, and primary motor cortex (M1). The experiment showed that 'augmentation influenced key aspects of hand representation and motor control'.[1145] The findings also showed that although the brain was very plastic and adaptable to accepting an extra finger: 'participants showed significant improvements in augmented hand motor performance across multiple task',[1146] the neural adaptation came at a cost. Increased cognitive load demands were predicted to decrease with practice, proficiency and use.[1147] More importantly, augmentation went so far as to incur 'changes to the biological hand representation' after use, meaning after removing the Third Thumb. Thus, unpredictably altering the brain's neural pathways. The study's findings profoundly demonstrate that hand augmentation with the Third Thumb resulted in an 'increased explicit sense of embodiment over the Thumb, a key goal for successful augmentation, whereas implicit body [representation] image was found to be stable.'[1148] These findings challenge ideas about body representation, especially when it comes to 'tool body integration', which traditionally thought that tool use would update the biological body representation.[1149] However, as the authors, Keileba et al., suggest from their study, tools do not require a radical change in hand function, unlike hand augmentation with a Third Thumb. The authors of this study suggest a greater need for a 'long-term motor augmentation' examination of biological hand representation.[1150] This study is a detailed research project that forms part of a larger body of work,[1151,1152] by the *Brain Plasticity Lab* and UCL. There is a greater deal of information covering analysis that looks at syndactyly (where two or more fingers are congenitally fused) and polydactyly (where there is a congenital supernumerary function

[1143] Lane, "Robotic 'Third Thumb' use can alter brain representation of the hand."
[1144] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p5.
[1145] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p1.
[1146] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p5.
[1147] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p6.
[1148] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p3,6.
[1149] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p6.
[1150] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p6.
[1151] Amoruso et al., "Somatosensory signals from the controllers of an extra robotic finger support motor learning."
[1152] Kieliba Paulina et al., "Neurocognitive consequences of hand augmentation," (Cold Spring Harbor: Cold Spring Harbor Laboratory Press, 2020).

that involves more than five fingers on the hand).[1153] Putting these neurological details of the study aside, what is remarkable is the foresight of the *Brain Plasticity Lab* in considering collaboration with an artist.

I have described Clode's Third Thumb in Chapter 3, which explores various SRFs, but I want to take this opportunity to consider it as a transitional object in the new world order. Danielle Clode's design captures something that traverses art, affect, biology, ethology, tool, body part, and experience via multidimensional references to the other, stimulating, inspiring, and exceptionally different from all other SRF designs. The Third Thumb taps into the universal set of ideas and connections that revitalise deeply unconscious notions about hand augmentation and the body as a whole (seen in Figure 53 and Figure 54).

Figure 54 - Showing Third Thumbs abduction and adduction taken from the paper by Kieliba et al.

Figure 55 - Deeply evocative images of Danielle Clode's design for the Third Thumb taken from her website[1154]

[1153] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p7.
[1154] Danielle, "Dani Clode An augmentation designer exploring the future body."

Here is a transversal image of subjectivity outside the set of inventions, which also situates its maker as deeply creative, insightful (a somewhat transversal subject herself), on a bridge that carries prosthetics, limbs, bodies, and subjectivities. On her website, she is described in the following way:

> Dani Clode's multi-disciplinary collaborative approach to design investigates the architecture and perception of our bodies. Incorporating new materials and design processes, the mechanics of the human body and robotics, Dani works to challenge the perception and boundaries of prosthetic design and extend the human form.[1155]

Another article gives more details on how Clode's Third Thumb works:

> Third Thumb is 3D-printed, making it easy to customise, and is worn on the side of the hand opposite the user's actual Thumb, near the little (pinky) finger. The wearer controls it with pressure sensors attached to their feet on the underside of the big toes. Wirelessly connected to the Thumb, both toe sensors control different movements of the Thumb by immediately responding to subtle changes of pressure from the wearer[1156]

The Third Thumb was originally designed with able-bodied people in mind. It is actuated by two motors which are controlled by 'pressure sensors fixed to the underside of the big toes of the user's feet', allowing for proportional pressure of feet-to-finger movement control.[1157] The fingers can abduct and adduct, moving the finger laterally (across the hand), while also flexing and extending, providing two degrees of movement, as shown in Figure 54. The motors that drive the finger are mounted on a wrist strap, while the batteries that power it are worn on the arm. The sensors are powered by batteries strapped to the ankle and emit signals wirelessly to the Third Thumb.[1158] The architecture of this device is rather elegant.

[1155] Danielle, "Dani Clode An augmentation designer exploring the future body."
[1156] Lane, "Robotic 'Third Thumb' use can alter brain representation of the hand."
[1157] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p2.
[1158] Kieliba et al., "Robotic hand augmentation drives changes in neural body representation," p2.

Figure 56 - The various components of the Third Thumb, showing batteries, motors, sensors, wireless microcontroller components and the Third Thumb itself, taken from Danielle Clode's website[1159]

Clode's understanding of the importance of good design and the significance of her prosthetic offers us insights. She suggests that, '[a]ugmentation is about designing a new relationship with technology—creating something that extends beyond being merely a tool to becoming an extension of the body itself.'[1160] In her *TEDx* Vienna talk, Clode describes her intention in designing the Third Thumb as:

> a catalyst for discussion. A bridge between design and neuroscience and a really unique experience. […] The words we use to describe our bodies and the bodies of other individuals is important. When we use words like missing, deficient, fix, false, or replica to describe someone, it means something. It implies there is a human baseline of normal. And it's not.[1161]

The ideas espoused by Clode are transformational in their approach to SRFs, as they directly target the concept of subjectivity (and semiotics), which Guattari and the aims of this dissertation have been investigating. Clode is catalysing, herein, a discussion of Guattari's ideas on subjectivity, which touches on all these themes of transversality that bracket language (semiotics), machinic ruptures, assemblages of enunciation, rhizomic thinking, an object of desire, transference, and habitual thinking. As an object of both material (human and non-human) and psychosocial messaging, the Third Thumb thus becomes a transitional object containing all the various characteristics of

[1159] Danielle, "Dani Clode An augmentation designer exploring the future body."
[1160] "Getting to grips with an extra thumb It's easier than you might think," University of Ambridge, 2024, accessed 10/07/2024, 2024, https://www.cam.ac.uk/stories/third-thumb.
[1161] TEDx Talks, "Why I Created a Third Thumb | Dani Clode | TEDxVienna," in *TEDxVienna* (https://www.youtube.com/, 2018). https://www.youtube.com/watch?v=UD_LwZD2Kls.

transversality discussed so far. These ideas to which Clode refers are encapsulated in the idea of transversality, through which this dissertation passes.

Danielle Clode's Third Thumb as an object of desire

Guattari has shared his psychoanalytical thoughts on group fantasy and its pitfalls, illustrated through examples found in the transference of messages, such as prestige and efficiency, within institutions. I have also referred to Guattari's preference for using transitional objects and object theory to enrich the analysis of expressions of groups and the understanding of messages disseminated by institutions. Suppose we consider a Third Thumb or any SRF an object of desire. In that case, it does not necessarily imply that it is an operative group fantasy. Instead, the Third Thumb can be thought of as an object of desire that expresses unconscious oneiric creativity, similar to transitional objects. I would consider the Third Thumb to be imbued with the very expressions of creativity, as cultures have adorned their bodies with objects for many millennia to elaborate on their references to the cosmos and ideas that express their kinship. The Third Thumb or many-body type technologies can be thought of as having a similar relationship, if not one that crosses into ideas of embodiment more intrinsically, making it a more intense relational system.

Guattari relegates the unserviceable pure reading of objects toward a fixed symbolic order and system of signifiers that reference structures like:

> "mathemes of the unconscious" based on fixations on the mother's breast, based on a certain economy of the anal object present in the entire social field, based on a certain logic of the phallic object present in all the power relations that can be interpreted in the social field.[1162]

Guattari instead delivers a dynamic transitional object that serves as a messenger, capable of reading and interpreting the functional connections between the various systems and structures arising from institutions and groups in society. This elaborates on a broader reading of subjectivity, which is expressed and reconciled between the inner world and outer reality, impacting subjectivity. Guattari hence places the 'process of singularization that takes place at the fantasmatic level of the object of desire'[1163] and is on the road to autonomy as the primary process that is reinforced by using such analysis. This means that Guattari places the transitional object at the centre of desire in

[1162] Guattari, *Molecular Revolution in Brazil*, 1, p305.
[1163] Guattari, *Molecular Revolution in Brazil*, 1, p52.

all relations when speaking of exchanges of messages that interact and trace the analytical processes of subjectivity.[1164]

Hence, Guattari seeks a multivalent object (such as Claude's Third Thumbs) that serves as the engine for transferring the denotation of all desire at the heart of the object exchange process. He would place this multivariant object (the object of desire) in the ambiguous zone that permits transversality (at the boundary of the inside and outside of the individual) to seep deep into the radical decentering of subjectivity. Guattari says this decentering has no specific truths or models of reference (such as how we think of the body's erogenous zones, which brings about the connections with the other).[1165] Guattari explains it in this way:

> The object of desire decenters the individual outside himself, on the boundaries of the other; it represents the impossibility of any complete refuge of the self inside oneself, but equally the impossibility of a radical passage to the other. Individual phantasy represents this impossible merging of different levels; it is this that makes it different from group phantasizing, for a group has no such "hitching posts" of desire on its surface, no such reminders of the order of specific truths as the body's erogenous zones, and their capacity for touching and being touched by other people.[1166]

A transitional object and object of desire, such as a Third Thumb, can be that messenger acting as the decentering mechanism in the 'radical passage to the other'. It can convey the 'specific truths' about ourselves that Guattari mentions. In this light, Clode's Third Thumb works as the very shuttle of resistance that takes and transforms itself into the object of desire and transfigures the subject and tries to make meaning of those wishes to rediscover the inner self and interacts with the outer world, connecting Guattari's infrahuman and interpersonal that I have previously discussed.[1167]

Clode's Third Thumb might be a Guattarian machinic assemblage and, by Clode's own accounts, it is a bridge that augments a 'new relationship with technology — creating something that extends beyond being merely a tool to becoming an extension of the body itself.'[1168] This 'becoming' thus takes subjectivity into a new order of expression and states of experience by expanding into Guattari's ideas on how transversality in subjectivity is actualised. Clode's Third Thumb connects what is human and non-human, giving voice to Guattari's ideas on technicity, machinic connectivity, and assemblages of enunciation (assemblages that make themselves known, organised, recognised, heard, disruptors, and coveners of reciprocity). This connection of various modalities of

[1164] Guattari, *Molecular Revolution in Brazil*, 1, p54.
[1165] Guattari, *Molecular Revolution in Brazil*, 1, p339.
[1166] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p324.
[1167] Guattari, *Molecular Revolution in Brazil*, 1, p43.
[1168] Brierley, "Getting to grips with an extra thumb It's easier than you might think."

transversality exceeds the boundaries of static subjectivity, advancing Guattari's idea in line with the ideas presented in this dissertation on a third-thumb, with particular reference to the SRF designed by Clode as a specific type of subjectivity I term techno-subjectivity. Techno-subjectivity is an escape into freedom, characterised by an open relationship between technology and context. Techno-subjectivity (and the transitional objects it draws upon) calls on relationships formed between the body and an object, in this case a third-thumb that intimately expresses their intertwined complexity together with its environmental instances, where it causes disruptions in hierarchies of social and political discourse of the body, the mind, and the various economies of habitual subjectivity, giving way to transversality, singularity, agency and autonomy of subjectivity.

Closing remarks

The Third Thumb is, in so many respects, an enunciation about how we wish to live, how we identify ourselves, and what manner of possible other is contained in us. Changing the body's shape can be seen as a transferential phenomenon of a transitional object from the unconscious, an oneiric expression of desire that has the potential for transversal connections to unimagined aspects of life, our unconscious, which expresses our collective connection to the earth and its varying conditions. There is potential to interpret history with a newly refreshed lens of understanding, opening up various impasses to understanding of the past, and changing our relation to the politics of space and place (found in territorialised relations to objects and subjects). Such permissibility would enable the next human evolutionary epoch in science, culture, technology, politics, and our interaction with our environment to be transformed by our understanding of the spaces and superstructures of the cosmos we inhabit. After all, evolution can be considered an expression of desire, a desire to explore and reconcile differences not only in science but also in differences far beyond comprehension, which are the precursors to primordial life, the life before life. The idea of transversality that Guattari suggests can reset our modern world and propel humanity's ecology on a new (re)evolutionary path, allowing all species to be part of the analytical process that makes experiences a special part of the intangible consideration of differences as an integral part of subjectivity. This process would be part of a self-perpetuating endeavour to be radical, seeking new experiences to broaden subjectivity. Clode says 'prosthesis sits in at a unique crossover point between tool, sculpture, experience and body part'[1169] , and she describes it visually in her *TEDx* Talks diagram seen in Figure 56. The translational meaning of this thinking, expressed by Clode, is

[1169] Talks, "Why I Created a Third Thumb | Dani Clode | TEDxVienna."

the core of Guattari's idea on transversality, which brings the organic and inorganic dimensions of the sculptural, the tool, and the experience into an object (prosthetic) elevated into a relation that exceeds the sum of its parts, becoming a psychosocial vector of expression.

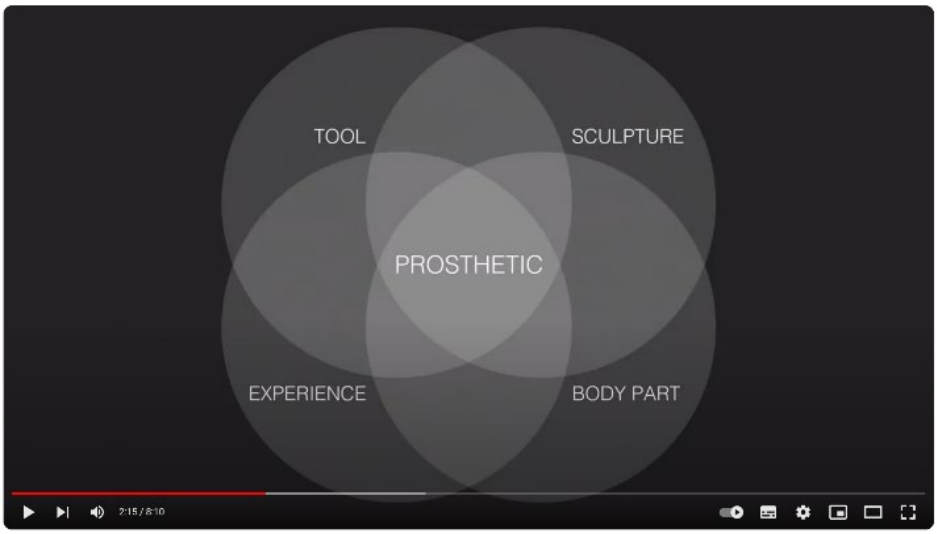


Figure 57 - Danielle Clode's schematic of the various dimensions of the Third Thumb shows experience as a significant undertaking in augmentation. Taken from her TEDx Talks broadcast on YouTube[1170]

Let's consider our current relation to other objects, objects of relation, *objects petit a*, or our powerful relation to partial objects. If we consider our bodies reflected in very structured and stable ways as partial objects - two hands, two breasts, one penis, two feet, and in most cases, two eyes, a nose and two hands with five fingers then the analytical discourse about our bodies shall never be changed, because our relations to those objects remain trapped in very constructed ways of understanding. So far, we have not broken this morphological illusion, except for the one centred around what is considered normal, which has been an idea that has been very inelastic. When we consider those with a missing thumb, a missing leg, or other type of bodily difference, we know them as minorities or those with lost abilities—we use the pejorative term such as 'disabled people'. This is our transference, just as we see the castration complex, the lack and deficiency that drives us to return to the image of the body in a stable, habitual way.

Clodes manifests the body in different terms; she sees the body as open to change, reimagined in many formats, even those that entail the world of ethology with a melding of human and bestial prosthetic creations. We see this in Clode's other work, The Vine Arm project, a collaboration between Dani Clode, *The Alternative Limb Project*, Jason Taylor and Hugo Elias.[1171] In this project, we witness the transformation of a prosthetic into a true object of desire —a half-imaginatively

[1170] Talks, "Why I Created a Third Thumb | Dani Clode | TEDxVienna."
[1171] "The Vine Arm," 2012-2022, accessed 10/07/2024, 2024, https://www.daniclodedesign.com/thevinearm.

entwined conception of flora and fauna that merges with the body, worn by user and model Kelly Knox, who was born without her lower left arm (Figure 58).

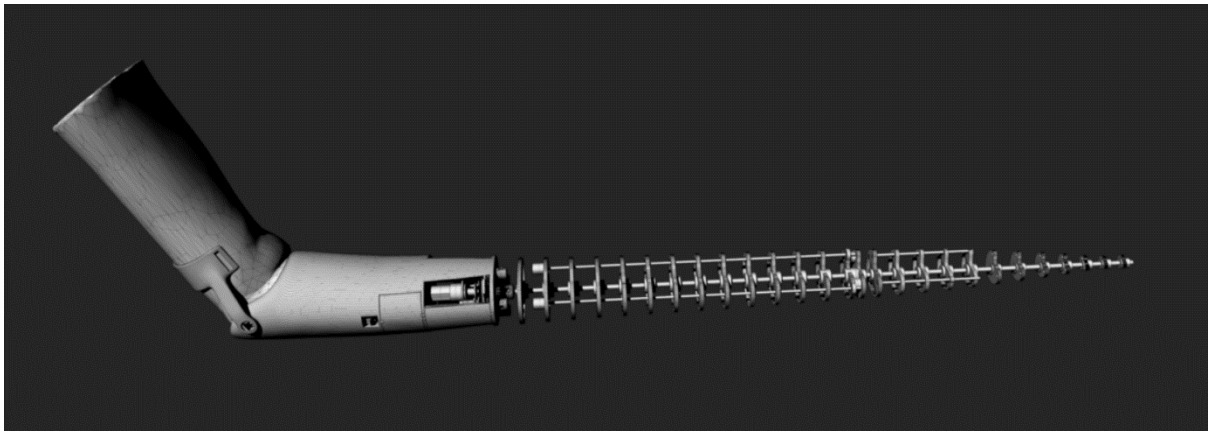


Figure 58 - The vertebral structure of The Vine Arm. Taken from Danielle Clode's website 'The Vine Arm'[1172]

Figure 59 - Kelly Knox becomes art, wearing The Vine Arm, designed for her with botanical adornments and an extra-terrestrial tail-like structure in place of a prosthetic arm, as seen on Danielle Clode's website.

[1172] Danielle, "The Vine Arm."

'Kelly chooses not to use prosthetics as an aid, but instead prefers to use them as an accessory to express her personality and explore aspects of her identity'.[1173] Knox expresses a desire to be different and explore her abilities in new ways by saying, 'I [want to] become the art'.[1174] Clode advises that:

> [t]he Vine Arm is a botanical/tentacle, flora/fauna hybrid explores the extra-terrestrial elements of Kelly Knox through a physical, reactive extension.
>
> Kelly Knox was born without her lower left arm, and throughout her life she never liked prosthetics and decided at a young age never to wear a 'traditional' one. "I feel like they are ugly, uninspiring, impractical and they are purely there to make me appear 'normal'. I don't want to be normalised." Kelly is passionate about changing the way society perceives disability by showing that disability can be fashionable, beautiful and powerful.
>
> Inspired by carnivorous plants, vertebrates and octopus tentacles, a botanical armour covers the upper surface of Kelly's arm. It connects to an alien structure beneath the skin: 26 individual vertebrae allow the movements of The Vine to be subtle and organic as it curves and curls around objects.[1175]

Knox's precise control of the vertebrae (Figure 57) is enabled by the four geared motors within the design, which she controls with her feet – more specifically, her big toes. With four force sensors embedded in her shoes, Knox can individually flex the four independently controlled sections or combine two at a time to create dynamic 'S' curves that can hold objects while reacting in real-time to Knox's movements. This prosthetic exemplifies Guattari's ideas on transversality, not just in its aesthetics, but also in its thoughts, experiences, and sensibilities. It also evokes the traversal coefficients of transversality in the project group and the interdisciplinary cooperation between the artist and technical teams, bringing into force the user's longing to be an artwork, rather than a disabled person seeking a prosthetic. This reinforces the analytical process of subjectivity, which seeks to determine its destiny, allowing the user, Knox, to be whole and not be subsumed by the psychoanalytical Freudian *lack* —the black hole of transference.

Here, the psychoanalytical idea of *lack* is interesting (discussed in Chapter 4D). Knox uses the lack to translate her multiple, differentiating transversal desire to be and become another, as opposed to conforming to the habitual person lacking and wanting. Instead, to become a true version of herself, Knox, a uniquely self-constructed and styled individual without any connection to the idea of corpus

[1173] "Kelly Knox," Altlimbpro, accessed 12/7/2024, 2024, https://thealternativelimbproject.com/in-depth/kelly_knox/.
[1174] Nemonolio, "Kelly Knox."
[1175] Danielle, "Dani Clode An augmentation designer exploring the future body."

normalis pressures, challenges the project of oneric creativity. On the other hand, the operation of Freud's concept of lack, entrenched in the politics of normativity, motivates other researchers in the field of SRF to produce a utilitarian prosthetic that completely misses the target of the ethics and aesthetics of deep human subjectivity. Instead, they capitulate to all the grids of control that dictate what is expected, resulting in the same outcome each time (that of a normative body). The boring, rigid, unattractive prosthetic that have been seen so far makes the users a conspicuous minority in the worst possible way when we contrast the SRFs reviewed to Clode's prototypes. The *lack* in these research studies operates ostensibly in the transference of the lack from their normative, idealised notion of the body, which is deeply unchallenged and subdues the true desire of the unconscious psyche. Like the Oedipal triangulation, the lack deployed in social models of societies deficient in unconscious coefficients of transversality are models of recoil trying to recover what is lacking rather than finding new bridges through the desire to evolve and respond in creative ways that unleash connections to ideas and desires yet unrealised. The operation of the *lack* in these homogenous societies of habitual social constructs is like the Lacan concept of *jouissance* (or surplus enjoyment, which incessantly moves towards Freud's death drive discussed in Chapter 4D), where there is an insatiable need always to come back to the modelled ideal body (to a normative, stable homogeneous configuration). As Clode suggests, '[w]hen we use words like missing, deficient, fix, false, or replica to describe someone, it means something. It implies there is a human baseline of normal. And it's not.'[1176] The body has a very stable schema in the psyche of individuals and the psychodynamics of the collective, but that doesn't mean it cannot be changed or challenged for the better. Thus, prosthetics in normative discourse is a social construct that replaces what is lost as a fallback position and has become a convention. In fact, according to Clode '[t]he word prosthesis come from the mid-sixteenth century Greek linguistic origin *prostithenai*, '*Pros*' towards, '*tithenai*' to place, to add to.'[1177] Clode suggests that the word 'prosthesis' inherently conveys the idea of augmentation from its inception.

To become a minority, like Knox's process of becoming art, is a process of self-discovery that involves augmenting oneself with technology, destabilising the relationship to the norm, society, and the politics of identity (as discussed in Chapter 2). A process that Guattari suggests brings the individual into the domain of becoming singularized within an assemblage composed of diverse connections, culminating in a unique assemblage of enunciation. A concept we have touched on. A prosthetic that exceeds a one-to-one replacement or an augmentation that supplements more than five fingers is the schizoanalytic movement of subjectivity into Guattari's concept of singularization.

[1176] Talks, "Why I Created a Third Thumb | Dani Clode | TEDxVienna."
[1177] Talks, "Why I Created a Third Thumb | Dani Clode | TEDxVienna."

This unique locus utilises transversality to supplement subjectivity and affect the unconscious process of the collective. Being part of the minoritarian movement is an idea Guattari has carefully distinguished as one that forces one to differentiate subjectivity via desires while building alliances with all other concepts of diversity.

Minoritarian resistance for recognition is done to be able to be self-styled, self-reconstructed outside the domain of dominant subjectivity, and reconfigure themselves through a transversal connection in line with their lifestyles and desires to become part of an inclusive new order (a Guattarian micropolitical revolution discussed in Chapter 2). Becoming, for Guattari, is an action of self-actualisation, as we have already touched on. Clode is also interested in becoming. There is a becoming art of the prosthesis as it is 'becoming an extension of the body itself.'[1178] In many ways, the psychoanalyst and the designer speak the same language and prompt similar outcomes for subjectivity when they discuss becoming and its relationship with desire.

When we work towards our true desires, a powerful relationship exists between translational, transformative, transgressive, and transversal forces, between the better ideas of the self and the collective. For Guattari, this becoming is the transversal movement into the new smoothness we have been discussing. Guattari suggests:

> So, for me, the new smoothness is the fact that, really, a becoming-woman, a becoming-plant, a becoming-animal, a becoming-cosmos can be inserted in the rhizomes of modes of semiotization, without thereby threatening the development of a society, the development of productive forces and things like that.[1179]

Guattari sees this becoming (like Knox's becoming art, becoming flora, becoming fauna) as a pathway of transversal manifestation when realised and actualised, ascending from one of many possibilities that emerge from rhizomic transversality. This is done without disrupting society, but in parallel with other social, political, and economic processes.

[1178] Brierley, "Getting to grips with an extra thumb It's easier than you might think."
[1179] Guattari, *Molecular Revolution in Brazil*, 1, p416.

Chapter 5 – Conclusion

The aim and how it was addressed

The dissertation, *Techno-Subjectivities: Architecture of the Third-Thumb*, aimed to explore the intersection of psychoanalytical ideas of subjectivity as proposed by Suely Rolnik and Félix Guattari and the field of Supernumerary Robotic Fingers (SRF), specifically the augmentation of a third-thumb. The dissertation aimed to counter the dystopian notion of augmentation that is so prevalent in the media and Hollywood. In doing so, it evoked the idea that the third-thumb might promote freedom and autonomy as well as construct a new type of subjectivity. The intersection of subjectivity and technics involves an analysis of various sub-themes of Guattarian subjectivity, while unravelling how they illuminate underlying intra- and inter-subjective processes and phenomena, as well as object relations. These relations intertwine various systems of understanding, enveloping broader social issues and the political dynamics of groups and individuals, on a path to unveiling the machinic unconscious and the realisations of desire. By analysing and deciphering these relations, subjective freedom is envisioned for the individual and their entanglement with the collective, allowing them to find their way to more open, just, and equitable environments.

The SRF, or the paradigm of the third-thumb, provides a basis for this negotiation because it becomes the gambit of social rupture that initiates debates about normativities, social relations, and understandings related to the stranglehold of various power structures on subjectivity. The current discourse and research on SRFs distance themselves so greatly from the wider social sphere that these issues are often hidden.

The exploration of this dissertation includes grasping the various inflections and forces in the social milieu that act upon the subjectivity of those engaging in augmentation with a third-thumb. The desire to do so may be a foray into opening and reshaping a richer interpretation of how we imagine and live our lives in concert with the technologies we surround ourselves with, embed within ourselves, and append. It is an outcome of this research that understanding how to envision a future with technologies (such as a third-thumb) helps the collective voice navigate the dialogics that form the social, political and economic fabric. The issues raised in this dissertation, through the praxis of augmenting a third-thumb, have a multiplier effect on the various dimensions of subjective life and also bridge the various impasses found in open modern societies. It also provides a cohesive force

that appears and can be a force before us when trying to find ways for cooperation, rather than an issue of identity politics and difference.

The objectives and how they were addressed

Prima facie, five key objectives were the primary drivers of this dissertation:

Objective 1: To explore the subjectivity that unfolds via Rolnik and Guattari's book, *Molecular Revolution in Brazil*

In my dissertation, my primary objective was to examine the concepts of Rolnik and Guattari, as presented in the *Molecular Revolution in Brazil*, with the aim of understanding their conception of subjectivity and its various operational dimensions. This investigation led me to explore numerous fundamental ideas and themes of subjectivity, encompassing the exploration of concepts such as schizoanalysis, the machinic, group therapy, transversality, revolution, and creativity, as well as the concept of new smoothness. Attached to these are also several subthematics, such as the meaning of identity, individuation (or serialised subjectivity), minorities and autonomy, desire, the unconscious, the process of singularization, the discourse of semiotics and its impact on the unconscious, the rhizome, micropolitics (micro and molar), Marxism (IWC) and resistance and Guattari's distinctive object theory.

I've examined how transversality functions simultaneously as an idea, tool, and psychoanalytical process that critiques conventional psychoanalysis while offering an alternative understanding of subjectivity. In my work, I've applied transversality to address the increasingly complex interactions between subjectivity, the unconscious, and the social/cultural forces intersecting with technics. These interactions manifest as assemblages of enunciation—transformative forces that materialise these ideas in concrete ways. This theoretical framework has enabled me to understand how Rolnik and Guattari, through their work in Brazil, catalysed vectors of subjectivity through dialogues with diverse social groups during Brazil's transition to democracy in the 1980s. Their approach has provided me with a rich foundation for investigating what I term 'techno-subjectivity,' particularly as embodied in the SRF, which serves not merely as a prosthetic but as a social molecular force that compels us to reconsider our understanding of architecture, the body, and technology.

Objective 2: Develop a thorough understanding of the field of Supernumerary Robotics Fingers (SRF)

In my dissertation, my second objective was to investigate the emerging field of SRFs and analyse the current discourse and visions of researchers in this domain. I began by contextualising the evolutionary significance of the human hand, particularly the opposable thumb, which has been crucial for human advancement through its role in tool manipulation and the development of social and political structures. This evolutionary context provided the foundation for my exploration of how technology might supersede biological development through techno-biological augmentation, potentially accelerating our evolutionary trajectory. Chapter 3 focused on this investigation, using the concept of an additional thumb as a paradigmatic instance for broader ideas about the technics of human-technological augmentation.

I conducted extensive research into various existing SRF types and mapped how these technologies are organised and classified. My analysis covered the proliferation of SRF technology over the past decade and a half, examining research areas, institutions, and the geographical distribution of work in this field. I investigated how SRFs are predominantly manufactured, their architectural design, component technologies, and the interfaces that enable human operation, including connections to our cognitive and neurological systems. I reviewed over thirty individual SRF designs, noting that while most weren't designed with commercial applications in mind, they collectively contributed to understanding the technical and usability challenges of SRF interoperability. Through this review, I identified that the field remains in its infancy, with various solutions attempting to balance trade-offs between grasp functionality, wearability, and comfort.

My evaluation highlighted that widespread adoption would require significant improvements in device wearability, aesthetic appeal, robustness, and weight reduction to minimise physical and cognitive impacts. Key considerations included functionality related to grip types, power ratios, dexterity levels, responsiveness, and adaptability for various types of disabilities and anatomical configurations. This comprehensive review established the technological foundation for my subsequent exploration of how SRFs might transform our understanding of the relationship between the body, technology, and architecture (which shall be discussed in the epilogue to this chapter).

Objective 3: Bring together two disparate fields of Rolnik and Guattari's subjectivity and the field of SRF

In my dissertation, the third objective was to explore the capacities and opportunities for Rolnik and Guattari's theoretical framework of subjectivity to rethink the field of SRFs. I gathered various

theoretical concepts from their work, supplemented by additional psychoanalytical writings from Guattari's texts, to create an intersectional analysis of SRF research. This analysis revealed how researchers' own subjectivity significantly influences the direction and outcomes of their projects.

I examined how researchers' subjective choices—from using piano-playing as a testing method to implementing Fin Ray technology for alternative grasping capabilities—shaped both their approach to solutions and the ultimate development of SRF technology. Through a Guattarian process of schizoanalysis, I provided insights into the underlying processes involved in researchers' choices, abilities, and personal backgrounds as they address challenges in the field.

The concept of the machinic as a component of transversality proved particularly valuable, revealing how the interconnection between the human body and mechanical SRF creates new assemblages that are fully machinic and cooperative. I explored how these assemblages transform from allopoietic (producing outputs different from themselves) to autopoietic systems that generate new forms of embodied experience and social relations when considered within the context of human-machine integration. Hubatschke would suggest it in this way: that '[m]achinic assemblages therefore combine both specific technologies and specific ideas of "humanness."'[1180]

Objective 4: To explore the socio-political implications of SRF technics through Guattari's theoretical lens (techno-subjectivity)

My fourth objective was to examine the broader social and political implications of SRF technology through the lens of Guattari's theory. I investigated how the third-thumb paradigm elicits what I term 'techno-subjectivity,' exploring how these technics might reshape social dynamics through local and individual advancement, tracing paths of subjective development through provocations and psychoanalytical processes. I considered how transmission systems—both the physical systems in SRF technology and epistemic functions within scientific discourse—are influenced by subjectivity and knowledge systems. The dissertation also addressed the potential impact of capital (IWC) on SRF development, highlighting tensions between economic territorialisation and more convivial systems of relationships.

Through examining innovative projects like Danielle Clode's work, I demonstrated how these technologies could exceed mere prosthetic function to become techno-socio-political tools for change. These projects exhibit characteristics of relatedness and cross-disciplinary cooperation, offering new ways of thinking that circumvent impasses while addressing diverse needs and desires.

[1180] Hubatschke, "How to Dance with Robots," p213.

By integrating Guattari's concept of molecular or micropolitics of subjectivity, I suggest that the technics SRF have the potential to construct a new social order that is conducive to diversity, embracing various techno-augmentative human-machine morphologies while enabling ethical agency that remains cognisant of our relationships with others (the new smoothness).

Objective 5: Prompting future thought on how techno-subjectivity implicates architecture

My fifth objective runs quietly throughout this dissertation, exploring how the dissolution of boundaries between body and machine creates new possibilities for subjective experience that extend beyond individual consciousness into broader social and architectural domains. Throughout my dissertation, I've examined how these augmentations destabilise conventional understandings of corporeality, creating what Guattari might call deterritorialised machinic assemblages where body and technology intertwine. When the boundaries between body and technology or body and architecture begin to blur, the very notion of architectural scale becomes reconceptualised. The spaces between object and subject transform from mere intervals into extended territories of corporeality, making architecture an extension of the flesh itself. This reconceptualisation renders architecture inherently political and micropolitical, connecting questions of human evolution and possible futures with aesthetic and design considerations.

The physical thresholds that once clearly delineated the body from the building now become zones of intensive exchange and mutual constitution: a smooth space. This shifts architecture from being simply about creating spaces to becoming an active participant in processes of corporeal becoming. When we consider architectural design in this light, we engage directly with questions about how human bodies might evolve and adapt within increasingly complex technological ecologies, making architectural decisions fundamentally tied to our collective future. This perspective is further elaborated in my conclusion, under the heading 'Epilogue: A return to architecture'.

Core outcomes as they relate to the aim/objectives

The dissertation negotiated the intersection of technics and subjectivity. The core outcomes culminate in what I call techno-subjectivity. Techno-subjectivity emerges at the intersection of transversal theory and SRF practice. It reframes technology not as an external tool but as an active participant in subject formation. It suggests that the 'dualism' of the two is flawed logic and that the relationship between the two is far richer. It reveals a complex relationship between our

unconscious, the intersecting worldviews of socio-politics and the sciences that produce the technology of the SRF. The SRF and all its derivative morphologies explored in the dissertation are not isolated technologies that stand alone; they are all deeply rooted in the social milieu, and their inventions have far-reaching ramifications. Working along the same lines as Hubatschke's research at the intersection of dance and robots, this dissertation also aimed not simply at making 'these technologies work, but in questioning the assemblages through which these technics are invented, researched, produced, experienced, and used.'[1181] Case studies illustrate this, such as the biomimetic SRFs inspired by fish fins and seal flippers that challenge engineering orthodoxy, or the SR3T piano project, which demonstrates augmentation as a creative act. Of course, there is Danielle Clode's Third Thumb, which operates as a transitional object, catalysing what Guattari calls the new smoothness—a fluid, inclusive social condition.

Ultimately, techno-subjectivity aligns with Guattari's ethico-aesthetic paradigm, positioning technology (and therefore its technics) as a vector for emancipation, diversity, and collective autonomy. It distances itself from the conflation of technology with deterministic capture, refusing the current dystopian framing to foster instead a generative passage toward territories where technics can engender flourishing subjectivities. It is the ethico-aesthetic dimension that sets transversality into motion—establishing reciprocity within the collective unconscious and inscribing social connectivity and responsibility into the very operations of techno-subjectivity. The psychoanalytical intertwining of this dissertation situates the SRF within the frameworks of transversality, which affects its expression through unconsciousness, its desires, and is expressed in Guattari's concept of collective assemblages of enunciation. The SRF operates through the unconscious of the individual and the collective in society, and the impact on the way we live our lives is profound. This dissertation allows the focus on SRF technology to shift toward its interconnectedness and the reverberating social, political and economic connectedness. This dissertation reveals several significant findings emerging from our exploration of the third-thumb or the field of SRF and its implications across technological, social, and political domains:

First, the thesis establishes techno-subjectivity as its core conceptual outcome: subjectivity is not fixed but produced through machinic assemblages of human and technological systems. Transversality opens semiotics and allows subjugated groups to become subject groups, as we see through the various chapters: chapter 4B, which talks about the machinic, and chapter 4C, which talks about the process of singularization. Thus, transversality via techno-subjectivity helps define

[1181] Hubatschke, "How to Dance with Robots," p219.

subjectivity as machinic, collective, and dynamic. The idea of third-thumbs is a catalyst for mutant subjectivities, which is discussed at length in chapters 4D and 4E, and finally in 4C.

Second, the emergence of techno-subjectivity through the technics of integration offers the recovery of creative desire flows that address contemporary issues of subjectivity in the right context (with high coefficients of transversality). The breaking of social boundaries through technological intervention creates potential for overcoming alienation and dismantling restrictive social barriers, allowing networks to form that access previously inaccessible territories of conscious and unconscious experience.

Third, the third-thumb paradigm reframes and moves us beyond the prosthetic paradigm toward a vision of augmentation as a micropolitical and psychoanalytic intervention, challenging normative subjectivity and capitalist semiotisation. This is detailed in 4A, where the value of people with polydactyly is discussed. It is also discussed in 4D: playing the Piano with SR3T, the Otariidae-inspired Soft Robotic Supernumerary Flippers using Kirigami and Origami Fabric Manipulation, and the Fin Ray-inspired gripper. The third-thumb paradigm moves us from the idea of a prosthetic for substitution to an existential territory of art and becoming, as discussed in Chapter 4A and 4E, where the body becomes a site for creating a wave of change. This change brings with it augmentation as a site for autonomy, creativity, and emancipation, as demonstrated in the discussion in Chapter 4A about how minorities are created, 4D how rare cases of desire can bring about change in the habitual, and 4E how desire can lead us in the transition to a new smoothness. We discovered that augmenting an SRF represents a profound political intervention that extends beyond mere technological enhancement. By examining the evolution of the hand through Napier's theoretical framework, we uncovered how the metastable morphology of the human hand—remaining relatively unchanged while other primates developed specialised appendages (Appendix 2)—contributed to our technics of development and cerebral evolution. This evolutionary history establishes the hand as a site of political significance long before modern societies emerged.

Fourth, the third-thumb paradigm introduces potential transformations in how bodies relate to their environments. The hand, as our primary tactile interface with the world, mediates most of our physical interactions with subjects and objects. Enhancing this interface creates a multiplier effect on neurocognitive capacities, potentially correcting power imbalances through expanded sensory awareness and environmental sensitivity.

Fifth, the speed and variety of ways technology is transforming our lives mean that technologies such as SRF can no longer be seen as mere utilitarian objects at the control of the anthropocentric ego. Emerging technologies are becoming increasingly intrinsically linked to our psychoanalytical life

and subjective well-being. As we seek freedom from various forms of enslavement to capital's metamodel, technology offers potential pathways through these negotiations. This bio-technological entanglement reconfigures leisure and desire as central components of living. While subjectivity takes centre stage in contexts where basic needs are met, it remains crucially linked to those yet to attain fundamental rights to survival, food, shelter, and autonomy.

Sixth, our analysis of SRF reveals the creativity we bring to our understanding of ourselves and our bodies. This creativity possesses an aesthetic value that transforms how we relate to ourselves, envision our futures, and resonate with fundamental differences in others. This opening constitutes an 'ethico-aesthetic'[1182] dimension where subjectivity becomes receptive to alternative ways of living and relating to our context—whether other people, objects, organisms, inorganic states, or our broader environment. As a vitalising force, it breaks through normative boundaries and delimits forces of capital, dogmatic ideologies, theologies, and hegemonic pressures. It enables productive orientations towards social contexts and organisations, finding zigzagging paths to common ground, shared interests, and passion for life beyond conventional routes. This creative force operates with consistent consideration of ethical values in a contextual framework, always seeking harmony and reciprocal understanding, aiming for highly functioning societies that enable individuals to flourish in their uniqueness.

Seventh, by leveraging the collective social intelligence that emerges from enhanced sensory feedback, we can develop a more nuanced consciousness of our surroundings. This reconnects us with deeper forms of relationality—tapping into unconscious desires for environmental engagement that reflect our evolutionary history and its epigenetic influences. Such reconnection fosters balance between organic and inorganic realms, potentially restoring more horizontal social organisations reminiscent of less hierarchical archaic societies.

Eighth, our historical analysis revealed some of the mechanisms by which dominant ideologies, particularly during industrialisation, shaped subjectivity to maximise the extraction of bodily labour value. These practices channel desire into restricted understandings, conceptually (reinforced at times by Freudian and Lacanian frameworks of subjectivity). Guattari's critique extends desire beyond these capitalistic reductions, recognising its expression through all bodily connections and decisions, reflecting fractal patterns of creativity and desire rather than mere sexuality or leisure.

Ninth, Enhanced Ability Devices (EAD) like the third-thumb become metamodels for how intimately integrated technologies can rupture normative thought structures. This challenges fundamental

[1182] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p10.

impasses maintained by conservative ideologies, with the potential to transform them into more ethical frameworks. Simultaneously, this intervention liberates us from the containing power of language, a tool historically used to enforce normative body compositions and constrain subjective experience.

Tenth, what distinguishes ththe technics of augmentation-intervention is its capacity for micropolitical transformation without requiring the destructive schisms associated with traditional revolutionary change. The third-thumb's intimate connection to bodily architecture makes it uniquely powerful as a catalyst for psychoanalytic and political freedom, potentially establishing new paradigms of social cooperation through its direct engagement with bodily schema and subjective experience.

Eleventh, the field of SRF, like any other field of technology, will advance in ways we cannot fully anticipate, developing at unprecedented rates alongside complementary technologies, such as Brain-Machine Interfaces. These revolutionary advances will bring previously discussed outcomes into sharper focus. The imperative will increasingly become a social concern regarding how we deal with our bodies, institutional thought, and ethics as we integrate ourselves into a new techno-augmentative world. Rather than a revolutionary tsunami creating irreconcilable ruptures with negative social impacts, the micropolitical revolution offers gradual change driven at the grassroots by fundamental desires, ethics, and aesthetics that can help redistribute necessary structures equitably. This creates a context that values subjectivity and allows a smooth transition into a world where constant evolution isn't seen as a political divide between progressivism and conservatism, but rather a new smoothness of transitions toward a hyper-evolutionary track for humanity, with functioning politics and societies that value productive engagement within and between one another.

Twelfth, the semiotics of modern societies, embedded in the discourse on Enhanced Ability Devices (EADs), are deeply ingrained in the construction of subjectivity. By changing the way we perceive and experience the world and how we convey those signifiers and their object messengers, we can profoundly impact how the collective unconscious influences the singularization power of subjectivity in creating free, autonomous individuals with the ethics of interconnectedness and reciprocity in open and diverse societies.

These outcomes collectively suggest that the humble prosthetic SRF contains potential for profound social metamorphosis—a technological rupture that, within appropriate contexts, could transform how bodies relate to environments and each other, with far-reaching implications across economic, ethical, and sociological domains. It helps us understand how the paradigm of a third-thumb acts in

navigating the issues that are contested and need to be negotiated at all levels of society. It exemplifies how to create an environment of empathy and understanding, and how to improve relations between individual idiosyncratic expressions and the wider social systems and settings they create.

Expanded core outcomes and causal thought trajectories

Adjacent to the core outcomes discussed, other streams of thought emerge from the discussion of SRF and subjectivity. Reviewing the final chapter's findings reveals how machinic consciousness and assemblages of enunciation converge with SRF users. First, the examples of Danielle Clode and Kelly Knox demonstrate how philosophical and analytical processes translate into material social change. These enunciations transcend illocutionary and perlocutionary territories of language (and thus semiotics), targeting subjectivity itself. This highlights the importance of design processes that capture the forces of subject formation. Co-design approaches, placing users at the centre of creation, become essential to the object-subject merger that forms new assemblages of relations. As Guattari suggests, the power of a 'psychoanalytic partial object that is adjacent to the body'[1183] is as powerful as the transformational power of art. Meaning that the way desire works through partial objects (in psychoanalysis) is similar to how meaning works through aesthetic objects (in art). In this, he suggests that subjectivity is formed through the interrelation of object (relationships) and subject that makes up the assemblages of enunciation, which include 'instances of the production of subjectivity (machinic, ecological, architectural, religious, etc).'[1184] The prosthetic-turned-SRF-turned-third-thumb becomes art, transforming into a machinic being[1185] that emerges as a human-machine through augmentation (as shall be discussed later, which is transformational to how we consider architecture). The user's voice politicises and socialises this assemblage, creating transversal connections beyond mere body parts. Therefore, architects, designers, artists, scientists, roboticists, and other interdisciplinary practitioners must engage users in collectively designing the new world that the third-thumb enables. Power dynamics in such inventive processes require careful study and negotiation to ensure user-centric outcomes.

[1183] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p14.
[1184] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p14.
[1185] Guattari suggests 'Machinic subjectivity, the machinic assemblage of enunciation, agglomerates these different partial enunciations and installs itself, as it were, before and alongside the subject-object relation.'Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p24.

Secondly, aesthetics emerged as a crucial tangential outcome. The aesthetic dimension places users' desire and identity at the centre of subjectivity and its social enunciations. The ethical negotiations through aesthetic territories offer templates for resolving emotionally and subjectively charged issues (often manifest as identity politics in contemporary society). A key ethical consideration is ensuring that third-thumbs become ubiquitous, life-changing instruments accessible to all, rather than instruments that sequester power among the privileged. Scientists, designers and organisations must consider how to organise access to such technology. The modular kits reviewed in Chapter 3 suggest possibilities for home-customisable SRFs, demonstrating the need to democratise SRF technology through interdisciplinary co-design. This aligns with Guattari's ethico-aesthetic paradigm. Moreover, it prompts reconsideration of how we view the body - beyond its sexualisation, scientific scrutiny, and deployment in gender politics. The body isn't merely a container for subjectivity but rather the subjective creation of space, context and time. It exists not as a discrete entity, but as connective tissue that brings assemblages into and out of equilibrium. Viewing the body in flux, horizontally positioned on the axis of discourse and balancing relations across organic and inorganic ecologies, helps transcend our anthropological disdain for other matters.

Thirdly, the expanded insights include the role of aesthetics and ethics in shaping subjectivity, and the importance of sensory feedback for relationality. We see this through Kelly Knox's trauma and my own—the need to re-establish a sense of belonging through an aesthetic and ethical orientation. These feedback systems are not only technological and environmental; they are also semiotic, ethico-aesthetic, and integral to the process of singularization. They have been discussed throughout the various chapters as providing the very confidence for subjects to become self-styled, to extend reciprocity, and to feel confident in their environment, within a society that cares for them and sees them as equals.

Fourth, I also discussed the idea of emancipating scientists in chapter 4B to think differently and to break habitual scientific thinking about transmission and how their field operates, radicalising the very constructed, freeing desire to guide research. This idea also includes the additional outcome of this dissertation: the transmission of epistemology in the sciences and the structures that maintain their hold over scientific innovations. The dissertation's example of finding new ways to transfer electrons and electrical energy beyond wires illustrates how foundational ideas can and must be challenged, parallel to our questioning of normative views of subjectivity. These established ways of thinking often create intellectual silos and impasses.

Scientific thought and communication have tangible effects, from how we address communities and minorities (such as those with polydactyly) to how desire drives innovative solutions for overcoming

obstacles to future possibilities. The greatest scientific breakthroughs have emerged from those who follow their desire to break habitual thinking patterns. Thus, techno-subjectivity, as the negotiating point between Guattari's ideas on subjectivity and the field of SRF, opens up and critiques those that can guide scientists towards more interdisciplinary and open approaches.

Recognition of research gaps for future exploration

Given the specific focus of this dissertation, several important areas remain to be explored in future work. A key direction would be to investigate subjectivity and technics of a third-thumb as foundational to Guattari's later works, including his posthumously released 1992 book, *Chaosmosis: An Ethico-Aesthetic Paradigm*, and his 1996 publications, *Soft Subversions and Chaosophy, collections of essays, lectures, and interviews* that elaborate on his mature ideas on the psychoanalytics of subjectivity. Other crucial texts for future analysis would include Guattari's 1989 works *Schizoanalytic Cartographies* and *The Three Ecologies*. While concepts like transversality, assemblages of enunciation, and micropolitical revolution have been explored, many related ideas remain to be investigated, including tracing how his work connects to other philosophers, semioticians, sociologists and anthropologists who influenced his thinking. This philosophical underwriting would involve relating Guattari's work to that of other post-structural philosophers. Any further investigation must include the incorporation of psychoanalytical understandings and further elaboration of the semiotics in which Guattari is so well-versed.

When discussing SRF augmentation or the third-thumb, one inevitably encounters questions of embodiment that extend beyond the scope of this dissertation. The neurophenomenology, neuroscientific research, cognitive science of somatosensory feedback systems, and philosophical discourse surrounding studies like the Rubber Hand Illusion (RHI) would significantly enrich our understanding of the intersection between Guattari's psychoanalytical framework and techno-subjectivity. This naturally extends to emerging technologies, such as Brain-Machine Interfaces using AI systems, and the broader field of Human-Computer Interaction.

These investigations would benefit from incorporating perspectives from practitioners in BMI, AI phenomenology, neuroscience, and neurotechnology, alongside theoretical frameworks such as those of Gilbert Simondon and Bernard Stiegler, among other philosophers of technology. Understanding how different technologies shape and are informed by human embodiment raises crucial questions about their societal impact. The implications for gender divisions, minority groups,

desire, sexuality, and the numerous challenges society faces regarding diversity, equity, and inclusion are profound and warrant further investigation. This broader analysis would help ground Guattari's ideas on institutional psychotherapy within contemporary discourse around subjectivity and technics of third-thumb in even more substantive ways.

Future directions call for bridging robotics, psychoanalysis, architecture, and art—creating spaces for the flows of creative desire and resisting hierarchical, capital-driven norms —while looking to broader ideas and theories in art and science to guide the discourse. As well as looking at new models used by capital and their territorialisations of molecularity within current systems of territorialization and reterritorialization, to see whether techno-subjectivity can provide answers to them. And to extend the discourse to include other theorists.

Future directions stemming from this dissertation

Beyond the gaps already identified that fall outside the scope of this dissertation, several additional avenues merit further exploration. The dissertation highlighted the crucial role of creativity in subjectivity, with later chapters revealing the significance of art in technological development and its capacity to express desires and enrich subjectivity. The role of art in scientific ideation and innovation deserves deeper consideration, as evidenced by research utilising the piano for testing the Robotic Third Thumb (R3T) and Clode's collaborations with scientists at University College London's Institute of Cognitive Neuroscience, as well as her creation of the Third Thumb and Knox's Vine Arm. Interdisciplinary cooperation through art becomes essential when considering ethico-aesthetics, where art serves as a medium through which the transformation of subjectivity and its psychoanalytical affective impact drive the expansion of collective connections to others, the self, and the community. Art in technology promotes novel approaches to technical challenges, user-centred design perspectives, aesthetic considerations in functionality, innovative applications of existing technologies, and cross-disciplinary solutions. As demonstrated by SRF researchers, artists often push technical limitations through transversal thinking, helping uncover unexpected applications of scientific tools and technologies. Art excels at bridging human-machine interfaces through conceptualisation and experimentation, while questioning technological assumptions and humanising technical systems. Further studies could examine how art pushes technical boundaries, identifies new applications of SRF technology, and tests the limits of scientific capabilities, while uncovering ethical implications and social consequences.

Another natural extension would be to explore the relationship between mental health, technology, and architecture. Given this dissertation's examination of the psychoanalytic bonds between people and the technics of augmentation in creating free, flourishing subjectivities, future work could investigate how architectural design and supportive technologies might enhance built environments for those struggling to realise their agency.

While numerous extensions to this research are possible, a particularly noteworthy direction lies in evolutionary cybernetics. This field combines evolutionary theory, systems theory, and cybernetics to understand the adaptation and evolution of complex systems through feedback loops and self-organisation. These systems align with Guattari's concepts of transversality and rhizomic theory, tracing how self-organising principles help adapt behaviours to environmental changes. Feedback systems, like those in SRFs, expand our experience and modify our environmental and social responses, becoming more efficient at exchanging information between system components rather than promoting stratification and alienation. By subjecting these processes to biological evolution analysis, we can gain a deeper understanding of the co-evolution of technology and biology.

To conclude, and in deferring to the theorist who foregrounds this thesis, Guattari interrogates these ideas and suggests:

> Should we keep the semiotic productions of the mass media, informatics, telematics and robotics separate from psychological subjectivity? I don't think so. Just as social machines can be grouped under the general title of Collective Equipment, technological machines of information and communication operate at the heart of human subjectivity, not only within its memory and intelligence, but within its sensibility, affects and unconscious fantasms. Recognition of these machinic dimensions of subjectivation leads us to insist, in our attempt at redefinition, on the heterogeneity of the components leading to the production of subjectivity.[1186]

Guattari argues that technological and media machines should not be seen as separate from psychological subjectivity, as they directly shape and operate within human consciousness, memory, sensibility, and the unconscious. He emphasises that subjectivity is produced through heterogeneous components that include both human psychological elements and the technics of machinic/technological ones, rejecting any strict separation between the technological and the psychological realms. Thus, the idea of techno-subjectivity as proposed in this dissertation and its interaction between the transversal relationship found in SRF augmentation and the paradigm of a third-thumb leads me to suggest a new worldview of multiplicitous existence as 'Informatic

[1186] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p4.

subjectivity distances us at high speed from the old scriptural linearity'.[1187] This means we are being led to a new understanding of the polymorphic impact of technics of a third-thumb on subjectivity, which simultaneously affects the body, the mind, its senses, and sensibilities.

Epilogue: A return to architecture

As mentioned in the introduction to this thesis, a thread concerning architecture runs quietly but persistently throughout this dissertation—much like my own experience of viewing the world through the twin lenses of the body and technics. These developments demand a rethinking of architecture: not as a static form but as a machinic assemblage responsive to the conditions of augmented embodiment. This dissertation's exploration of subjectivity and the third-thumb paradigm illuminates crucial questions about architecture's future direction. While the Oxford English Dictionary defines architecture as 'the art or science of building or constructing edifices of any kind for human use,'[1188] we must reconsider architecture's historical fixation on particular modes of thought that have distanced it from its origins in bodily forms and shadows.

As technologies automate and transform architectural labour, the field must become more interdisciplinary, examining all areas where the body relates to the design of the body rather than design that steps away from it. Architecture should move beyond merely working adjacent to the body, protecting or sheltering it at scales greater than human proportion, to engage at scales proportionally smaller than the body. This means reconsidering ways of negotiating space beyond traditional division and territorialisation of site. As described by Guattarian ethico-aesthetics when speaking of assemblages of aesthetic desire, which cannot be fully explained in sets of Cartesian logic, this new assemblage of enunciation (SRF-human augmented set of logic) of the architecture of the third-thumb relates back to a field of architecture that (as Guattari suggests) has: 'neither inside nor outside. They are limitless interfaces which secrete interiority and exteriority and constitute themselves at the root of every system of discursivity.'[1189] New opportunities emerge to integrate and extend into space through the body's mobile characteristics and its biological, organic and inorganic integration with context and environment. Such feedback into architectural paradigms will

[1187] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p96.
[1188] "OED : Oxford English dictionary : the definitive record of English language."
[1189] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p92.

necessarily redefine how we think of architecture, pushing it toward more responsive and dynamic manifestations rather than static ones.

Architecture that emerges from and centres on the body must transform and respond to mind, social conditions, and political realities with greater vigour through novel means of embodiment and expression. My own thoughts and experiences of my childhood home suggest as much. The necessity to broaden architecture's purview beyond traditional multidisciplinary approaches to active engagement with bodily capacities is clear. Such reorientation could unshackle architecture from serving as an inanimate shell for capital and hegemonic forces, breaking its nexus with systems of social control and power. Architecture operating at mobile and smaller-than-body scales enables subjective expression and micropolitical activism to intertwine with how we use and define our bodies, supporting their emancipation from moral prisons and restrictive social mores that uphold conservative understandings of sexuality, sex, gender and their relation to desire. The body's destiny should be aided not only by its desires but also through architectural gesture.

This reconceptualisation positions architecture as truly interdisciplinary rather than a monodisciplinary monolith - not merely encasing space but extending into it, recognising space as an intersubjective social fabric laden with unseen attributes that architecture must engage cognitively, metaphorically, phenomenologically, psychologically, and epistemologically to question various scales of the built environment. The very term 'architecture' must reterritorialise its namesake. These ideas merit deeper exploration in future work to fully examine their implications for architectural practice and theory. Architecture emerges as a critical site of transformation: no longer static, but a dynamic, body-oriented practice that responds to augmented corporeality and fosters transversal relations. We see that in SRFS that have feedback loops and cognitive enmeshment with our environment. SRF technologies and the technics of of a third-thumb exemplify how way the brain is elastic in its response to changes in embodiment via technologies such as a third-thumb as well as their societal impacts. Thus, the body, technics of a third-thumb, and architecture are enmeshed in the process of subjectivation, otherwise known as techno-subjectivity.

Select Bibliography

Adkins, Brent. *Deleuze and Guattari's a Thousand Plateaus: A Critical Introduction and Guide.* Edinburgh: Edinburgh University Press, 2015. doi:10.3366/j.ctt1g0b18p.

Albuquerque, Victor, Alkinoos Athanasiou, and Sidarta Ribeiro. *Neurotechnology: Methods, Advances and Applications.* 2020. doi:10.1049/PBHE019E.

Amoruso, E., L. Dowdall, M. T. Kollamkulam, O. Ukaegbu, P. Kieliba, T. Ng, H. Dempsey-Jones, D. Clode, and T. R. Makin. "Somatosensory Signals from the Controllers of an Extra Robotic Finger Support Motor Learning." *bioRxiv* (2021): 2021.05.18.444661. https://doi.org/10.1101/2021.05.18.444661. http://biorxiv.org/content/early/2021/05/18/2021.05.18.444661.abstract.

Anderson, Susan Leigh. "Asimov's "Three Laws of Robotics" and Machine Metaethics." *AI & society* 22, no. 4 (2007): 477-93. https://doi.org/10.1007/s00146-007-0094-5.

Anumanchipalli, Gopala K., Josh Chartier, and Edward F. Chang. "Speech Synthesis from Neural Decoding of Spoken Sentences." *Nature (London)* 568, no. 7753 (2019): 493-98. https://doi.org/10.1038/s41586-019-1119-1.

Arzy, Shahar. "Agency, Ownership and the Potential Space." *Brain sciences* 11, no. 4 (2021): 460. https://doi.org/10.3390/brainsci11040460.

Audouze, Françoise. "Leroi-Gourhan, a Philosopher of Technique and Evolution." *Journal of archaeological research* 10, no. 4 (2002): 277-306. https://doi.org/10.1023/A:1020599009172.

Ayvali, Murat, Inge Wickenkamp, and Andrea Ehrmann. "Design, Construction and Tests of a Low-Cost Myoelectric Thumb." *Technologies (Basel)* 9, no. 3 (2021): 63. https://doi.org/10.3390/technologies9030063.

Barad, Karen Michelle. *Meeting the Universe Halfway Quantum Physics and the Entanglement of Matter and Meaning.* Durham: Duke University Press, 2007.

Bardin, Andrea. *Epistemology and Political Philosophy in Gilbert Simondon: Individuation, Technics, Social Systems.* Philosophy of Engineering and Technology. Vol. 19, Dordrecht: Springer Netherlands, 2015.

Bardo, Ameline, Marie-Hélène Moncel, Christopher J. Dunmore, Tracy L. Kivell, Emmanuelle Pouydebat, and Raphaël Cornette. "The Implications of Thumb Movements for Neanderthal and Modern Human Manipulation." *Scientific reports* 10, no. 1 (2020): 19323-23. https://doi.org/10.1038/s41598-020-75694-2.

Bartneck, Christoph, Tony Belpaeme, Friederike Eyssel, Takayuki Kanda, Merel Keijsers, and Selma Šabanović. *Human-Robot Interaction : An Introduction.* Cambridge: Cambridge University Press, 2020.

Bauer, Andrea, Dirk Wollherr, and Martin Buss. "Human-Robot Collaboration: A Survey." *I. J. Humanoid Robotics* 5 (03/01 2008): 47-66. https://doi.org/10.1142/S0219843608001303.

Berressem, Hanjo. *Felix Guattari's Schizoanalytic Ecology.* Edinburgh: Edinburgh University Press, 2020.

Bijker, Wiebe E., and John Law. *Shaping Technology/Building Society: Studies in Sociotechnical Change.* Inside Technology. Cambridge, Mass: MIT Press, 1992.

Blasi, Vincent. "Seana Shiffrin's Thinker-Based Freedom of Speech: A Response. (Symposium: Individual Autonomy and Free Speech)." *Constitutional commentary* 27, no. 2 (2011): 309.

Bluemink, Matt. "Gilbert Simondon and the Process of Individuation." *Epoché Philosophy Monthly*, Sep 2020. https://epochemagazine.org/34/gilbert-simondon-and-the-process-of-individuation/.

Borden, Iain, and Katerina Rüedi Ray. *The Dissertation: A Guide for Architecture Students.* Third edition. ed. Oxford: Routledge, 2014. doi:10.4324/9781315795256.

Botvinick, Matthew, and Jonathan Cohen. "Rubber Hands 'Feel' Touch That Eyes See." *Nature (London)* 391, no. 6669 (1998): 756-56. https://doi.org/10.1038/35784.

Braidotti, Rosi. *Nomadic Subjects : Embodiment and Sexual Difference in Contemporary Feminist Theory.* Gender and Culture. New York: Columbia University Press, 1994.
———. *Nomadic Theory: The Portable Rosi Braidotti.* Gender and Culture. New York: Columbia University Press, 2012. doi:10.7312/brai15190.
"Ehrsson Laboratory." Karolinska Institutet, 2022, accessed 4/10/2022, 2022, https://ki.se/en/neuro/ehrsson-laboratory.
Braumann, Johannes, and Sigrid Brell-Cokcan. *Robarch 2012: Robotic Fabrication in Architecture, Art and Design.* Springer, 2012.
Brett, Guy. "Lygia Clark: In Search of the Body." In *Art in America*. California State University, 1994.

http://www.csus.edu/indiv/o/obriene/art111/readings/InSearchoftheBody.pdf.
"Getting to Grips with an Extra Thumb It's Easier Than You Might Think." University of Ambridge, 2024, accessed 10/07/2024, 2024, https://www.cam.ac.uk/stories/third-thumb.
Brunner, Christoph. "Towards a New Aesthetic Paradigm Ethico-Aesthetics and the Aesthetics of Existence in Foucault and Guattari." In *RADAR Musac Journal of Art and Thought*. www.academia.edu, 2012.
Bryant, Levi R. *The Democracy of Objects.* New Metaphysics. 1st ed. ed. Ann Arbor: Open Humanities Press, 2011.
Bubshait, Dalal K. "A Review of Polydactyly and Its Inheritance: Connecting the Dots." *Medicine (Baltimore)* 101, no. 50 (2022): E32060-e60. https://doi.org/10.1097/MD.0000000000032060.
Buchanan, Ian. *Deleuze and Guattari's 'Anti-Oedipus': A Reader's Guide.* Reader's Guides. London: Bloomsbury Publishing Plc, 2008.
Burch, Robert. "Charles Sanders Peirce." In *Stanford Encyclopedia of Philosophy*. First published Fri Jun 22, 2001; substantive revision Thu Feb 11, 2021, 2021. https://plato.stanford.edu/entries/peirce/.
Callen, Donald. "Guattari's Machinic Unconscious and Proust as Schizoanalyst." *Rhizomes* 23, no. 1 (2012).
Canguilhem, Georges. *Ideology and Rationality in the History of the Life Sciences.* Cambridge, Mass: MIT Press, 1988.
———. *Machine and Organism.* Translated by Mark Cohen & Randall Cherry. Edited by Jonathan Crary and Sanford Kwinter. New York: Zone Books, 1992. Incorporations.
———. *The Normal and the Pathological.* New York: Zone Books, 1989.
Canguilhem, Georges, and François Delaporte. *A Vital Rationalist : Selected Writings from Georges Canguilhem.* New York: Zone Books, 1993.
Canguilhem, Georges, Paola Marrati, and Todd Meyers. *Knowledge of Life.* Ashland, Ohio: Fordham University Press, 2009.
Chabot, Pascal, Aliza Krefetz, and Graeme Kirkpatrick. *The Philosophy of Simondon between Technology and Individuation.* London: Bloomsbury, 2003.
Chancel, Marie, and H. Henrik Ehrsson. "Which Hand Is Mine? Discriminating Body Ownership Perception in a Two-Alternative Forced-Choice Task." *Attention, perception & psychophysics* 82, no. 8 (2020): 4058-83. https://doi.org/10.3758/s13414-020-02107-x.
Chancel, Marie, H. Henrik Ehrsson, and Wei Ji Ma. "Uncertainty-Based Inference of a Common Cause for Body Ownership." *eLife* 11 (2022). https://doi.org/10.7554/eLife.77221.
Chancel, Marie, Heather Iriye, and H. Henrik Ehrsson. "Causal Inference of Body Ownership in the Posterior Parietal Cortex." *The Journal of Neuroscience* 42, no. 37 (2022): 7131. https://doi.org/10.1523/JNEUROSCI.0656-22.2022. http://www.jneurosci.org/content/42/37/7131.abstract.
Chang, Edward F. "Towards Large-Scale, Human-Based, Mesoscopic Neurotechnologies." *Neuron (Cambridge, Mass.)* 86, no. 1 (2015): 68-78. https://doi.org/10.1016/j.neuron.2015.03.037.

Chella, Antonio, Angelo Cangelosi, Giorgio Metta, and Selmer Bringsjord. "Editorial: Consciousness in Humanoid Robots." *Frontiers in robotics and AI* 6 (2019): 17-17. https://doi.org/10.3389/frobt.2019.00017.

Ciullo, Andrea S., Manuel G. Catalano, Antonio Bicchi, and Arash Ajoudani. "A Supernumerary Soft Robotic Hand-Arm System for Improving Worker Ergonomics." Biosystems & Biorobotics, 520-24. Cham: Springer International Publishing.

Clarissa, Angelina, Fransiskus Chandra, Medhavini Tanuardi, Virnanto Buntarja, Anindya Susanto, and Nurul Paramita. *Brain Machine Interface (Bmi) for Prosthetic Limb Real Applications in Human: A Scoping Review.* 2021. doi:10.13140/RG.2.2.35980.03206.

Coeckelbergh, Mark. "Moral Appearances: Emotions, Robots, and Human Morality." *Ethics and information technology* 12, no. 3 (2010): 235-41. https://doi.org/10.1007/s10676-010-9221-y.

Collinger, Jennifer L. PhD, Brian PhD Wodlinger, John E. B. S. Downey, Wei PhD Wang, Elizabeth C. M. D. Tyler-Kabara, Douglas J. PhD Weber, Angus J. C. PhD McMorland*, et al.* "High-Performance Neuroprosthetic Control by an Individual with Tetraplegia." *The Lancet (British edition)* 381, no. 9866 (2013): 557-64. https://doi.org/10.1016/S0140-6736(12)61816-9.

Cox Cameron, Olga, and Carol Owens. *Studying Lacan's Seminar Vi: Dream, Symptom, and the Collapse of Subjectivity.* Studying Lacan's Seminars. Milton: Taylor & Francis Group, 2021.

Crooks, Whitney, Gabrielle Vukasin, Maeve O'Sullivan, William Messner, and Chris Rogers. "Fin Ray® Effect Inspired Soft Robotic Gripper: From the Robosoft Grand Challenge toward Optimization." *Frontiers in robotics and AI* 3 (2016). https://doi.org/10.3389/frobt.2016.00070.

Cunningham, James, Anita Hapsari, Pierre Guilleminot, Ali Shafti, and A. Aldo Faisal. "The Supernumerary Robotic 3rd Thumb for Skilled Music Tasks." 2018.

D'Anna, Edoardo, Giacomo Valle, Alberto Mazzoni, Ivo Strauss, Francesco Iberite, Jérémy Patton, Francesco M. Petrini*, et al.* "A Closed-Loop Hand Prosthesis with Simultaneous Intraneural Tactile and Position Feedback." *Science robotics* 4, no. 27 (2019). https://doi.org/10.1126/scirobotics.aau8892.

"Controllable Third Thumb Lets Wearers Extend Their Natural Abilities." YouTube, July 2017, 2023, https://www.youtube.com/watch?v=TY6Dm4Klumc.

"Dani Clode an Augmentation Designer Exploring the Future Body." 2012-2022, accessed 10/07/2024, 2024, https://www.daniclodedesign.com/.

"The Vine Arm." 2012-2022, accessed 10/07/2024, 2024, https://www.daniclodedesign.com/thevinearm.

Dautenhahn, Kerstin, and Joe Saunders. *New Frontiers in Human-Robot Interaction.* Advances in Interaction Studies (Ais), V. 2. Amsterdam ;: J. Benjamins Pub., 2011.

Daylight, Russell. "The Difference between Semiotics and Semiology." *Gramma Journal of Theory and Criticism* 20 (2014): p37-50. https://researchoutput.csu.edu.au/en/publications/the-difference-between-semiotics-and-semiology.

De Boever, Arne. *Gilbert Simondon : Being and Technology.* Edinburgh: Edinburgh University Press, 2012.

De Landa, Manuel. *Assemblage Theory.* Speculative Realism. Edinburgh: Edinburgh University Press, 2016.

———. *Intensive Science and Virtual Philosophy.* Transversals. London ;: Continuum, 2002.

———. *A New Philosophy of Society : Assemblage Theory and Social Complexity.* Bloomsbury Revelations. First edition. ed. London ;: Bloomsbury Academic, 2019. doi:10.5040/9781350096769.

———. *Philosophy and Simulation : The Emergence of Synthetic Reason.* Bloomsbury Revelations. First edition. ed. London ;: Bloomsbury Academic, 2019. doi:10.5040/9781350096806.

de Vignemont, Frédérique. "Embodiment, Ownership and Disownership." *Consciousness and Cognition* 20, no. 1 (2011/03/01/ 2011): 82-93.

https://doi.org/https://doi.org/10.1016/j.concog.2010.09.004. https://www.sciencedirect.com/science/article/pii/S1053810010001704.
Delanda, Manuel. *Materialist Phenomenology: A Philosophy of Perception (Theory in the New Humanities).* Theory in the New Humanities. Bloomsbury Academic, 2021.
Deleuze, Gilles. *The Fold : Leibniz and the Baroque.* Continuum Impacts. [Rev. ed.]. ed. London ;: Continuum, 2006.
———. *Foucault.* London: Athlone, 1988.
———. *Francis Bacon : The Logic of Sensation.* London ;: Continuum, 2003.
———. "Postscript on the Societies of Control." *October* 59 (1992): 3-7.
Deleuze, Gilles, and Anne Boyman. *Pure Immanence : Essays on a Life.* New York: Zone Books, 2001.
Deleuze, Gilles, and Félix Guattari. *A Thousand Plateaus : Capitalism and Schizophrenia.* Bloomsbury Revelations. London: Bloomsbury Academic, 2013.
Deleuze, Gilles, Félix Guattari, and Stefano Di Riccio. *Rizoma.* Le Forme Del Discorso ; 1. Parma ;: Pratiche editrice, 1977.
Deleuze, Gilles, Guattari, Félix. *A Thousand Plateaus : Capitalism and Schizophrenia.* Translated by Brian Massumi. Bloomsbury Revelations. London: Bloomsbury Academic, 2021.
Deleuze, Gilles, and Eugene W. Holland. *Deleuze and Guattari's Anti-Oedipus : Introduction to Schizoanalysis.* Anti-Oedipus. London ;: Routledge, 1999. doi:10.4324/9780203007426.
della Gatta, Francesco, Francesca Garbarini, Guglielmo Puglisi, Antonella Leonetti, Annamaria Berti, and Paola Borroni. "Decreased Motor Cortex Excitability Mirrors Own Hand Disembodiment During the Rubber Hand Illusion." *eLife* 5, no. 2016 (2016). https://doi.org/10.7554/eLife.14972.
Di Pino, Giovanni, Angelo Maravita, Loredana Zollo, Eugenio Guglielmelli, and Vincenzo Di Lazzaro. "Augmentation-Related Brain Plasticity." *Frontiers in systems neuroscience* 8, no. JUNE (2014): 109-09. https://doi.org/10.3389/fnsys.2014.00109.
Dixon, Tim. "Magical Aesthetics: Subjectivity, Simondon, Animism, and the Aesthetic." www.academia.edu. https://www.academia.edu/19544426/Magical_Aesthetics_Subjectivity_Simondon_Animism_and_the_Aesthetic.
Dominijanni, Giulia, Solaiman Shokur, Gionata Salvietti, Sarah Buehler, Erica Palmerini, Simone Rossi, Frederique De Vignemont*, et al.* "The Neural Resource Allocation Problem When Enhancing Human Bodies with Extra Robotic Limbs." *Nature machine intelligence* 3, no. 10 (2021): 850-60. https://doi.org/10.1038/s42256-021-00398-9.
Dosse, François. *Gilles Deleuze & FéLix Guattari Intersecting Lives.* European Perspectives. New York: Columbia University Press, 2010.
Duffy, Brian, and Gina Joue. "Intelligent Robots: The Question of Embodiment." (01/01 2000).
Duffy, Brian, C. Rooney, Gregory O'Hare, and Donoghue. "What Is a Social Robot?". (10/20 2021).
Editor, Neuron. "Exploring Neurotechnologies." *Neuron (Cambridge, Mass.)* 86, no. 1 (2015): 1-1. https://doi.org/10.1016/j.neuron.2015.03.053.
Ehrsson, H. Henrik, Aikaterini Fotopoulou, Dominika Radziun, Matthew R. Longo, and Manos Tsakiris. "No Specific Relationship between Hypnotic Suggestibility and the Rubber Hand Illusion." *Nature communications* 13, no. 1 (2022): 564-64. https://doi.org/10.1038/s41467-022-28177-z.
Ehrsson, H. Henrik, Nicholas P. Holmes, and Richard E. Passingham. "Touching a Rubber Hand: Feeling of Body Ownership Is Associated with Activity in Multisensory Brain Areas." *The Journal of neuroscience* 25, no. 45 (2005): 10564-73. https://doi.org/10.1523/JNEUROSCI.0800-05.2005.
Ehrsson, H. Henrik, Charles Spence, and Richard E. Passingham. "That's My Hand! Activity in Premotor Cortex Reflects Feeling of Ownership of a Limb." *Science (American Association for the Advancement of Science)* 305, no. 5685 (2004): 875-77. https://doi.org/10.1126/science.1097011.

Ehrsson, H. Henrik, Katja Wiech, Nikolaus Weiskopf, Raymond J. Dolan, and Richard E. Passingham. "Threatening a Rubber Hand That You Feel Is Yours Elicits a Cortical Anxiety Response." *Proceedings of the National Academy of Sciences - PNAS* 104, no. 23 (2007): 9828-33. https://doi.org/10.1073/pnas.0610011104.

Ehrsson, Henrik H. "Chapter 8 - Multisensory Processes in Body Ownership." In *Multisensory Perception*, edited by K. Sathian and V. S. Ramachandran, 179-200: Academic Press, 2020.

Fan, Chenggui, Sara Coppi, and H. Henrik Ehrsson. "The Supernumerary Rubber Hand Illusion Revisited: Perceived Duplication of Limbs and Visuotactile Events." *Journal of experimental psychology. Human perception and performance* 47, no. 6 (2021): 810-29. https://doi.org/10.1037/xhp0000904.

Fang, Wen, Ruyuan Zhang, Yijie Zhao, Liping Wang, and Yong-Di Zhou. "Attenuation of Pain Perception Induced by the Rubber Hand Illusion." *Frontiers in neuroscience* 13 (2019): 261-61. https://doi.org/10.3389/fnins.2019.00261.

Ffrench, Patrick. "Guattari's Therapeutics: From Transference to Transversality." *Deleuze and Guattari Studies* 17, no. 2 (2023): 217-35.

Ficuciello, Fanny, Fabio Ruggiero, and Alberto Finzi. *Human Friendly Robotics: 10th International Workshop.* Springer Proceedings in Advanced Robotics. Vol. 7, Cham: Springer International Publishing AG, 2018.

Fiore, Stephen M., Travis J. Wiltshire, Emilio J. C. Lobato, Florian G. Jentsch, Wesley H. Huang, and Benjamin Axelrod. "Toward Understanding Social Cues and Signals in Human-Robot Interaction: Effects of Robot Gaze and Proxemic Behavior." *Frontiers in psychology* 4 (2013): 859-59. https://doi.org/10.3389/fpsyg.2013.00859.

Franco, Leonardo, Gionata Salvietti, and Domenico Prattichizzo. "Command Acknowledge through Tactile Feedback Improves the Usability of an Emg-Based Interface for the Frontalis Muscle." 2019.

Freud, Sigmund. *Beyond the Pleasure Principle.* Dover Thrift Editions. Newburyport: Dover Publications, 2014.

Freud, Sigmund, and A. A. Brill. *The Interpretation of Dreams.* Dover Thrift Editions. Newburyport: Dover Publications, 2015.

Fried, I., A. Katz, G. McCarthy, K. J. Sass, P. Williamson, S. S. Spencer, and D. D. Spencer. "Functional Organization of Human Supplementary Motor Cortex Studied by Electrical Stimulation." *The Journal of neuroscience* 11, no. 11 (1991): 3656-66. https://doi.org/10.1523/JNEUROSCI.11-11-03656.1991.

Friedrich, Orsolya. *Clinical Neurotechnology Meets Artificial Intelligence : Philosophical, Ethical, Legal and Social Implications.* Advances in Neuroethics. 1st ed. 2021. ed. Cham, Switzerland: Springer, 2021. doi:10.1007/978-3-030-64590-8.

Gaggioli, Andrea, Alice Chirico, Daniele Di Lernia, Mario A. Maggioni, Clelia Malighetti, Federico Manzi, Antonella Marchetti*, et al.* "Machines Like Us and People Like You: Toward Human–Robot Shared Experience." *Cyberpsychology, behavior and social networking* 24, no. 5 (2021): 357-61. https://doi.org/10.1089/cyber.2021.29216.aga.

Gemeinboeck, Petra. "The Aesthetics of Encounter: A Relational-Performative Design Approach to Human-Robot Interaction." *Frontiers in robotics and AI* 7 (2021): 577900-00. https://doi.org/10.3389/frobt.2020.577900.

———. "The Aesthetics of Encounter: A Relational-Performative Design Approach to Human-Robot Interaction." *Frontiers in robotics and AI* 7 (2020): 577900-00. https://doi.org/10.3389/frobt.2020.577900.

Gemeinboeck, Petra, and Rob Saunders. "Moving Beyond the Mirror: Relational and Performative Meaning Making in Human–Robot Communication." *AI & society* 37, no. 2 (2021): 549-63. https://doi.org/10.1007/s00146-021-01212-1.

Genosko, Gary. *Félix Guattari a Critical Introduction.* Pluto Press, 2009. doi:10.2307/j.ctt183p6gn. http://www.jstor.org/stable/j.ctt183p6gn.

———. *Felix Guattari an Aberrant Introduction.* Transversals. London ;: Continuum, 2002.
———. *Félix Guattari*

a Critical Introduction. Pluto Press, 2009. doi:10.2307/j.ctt183p6gn. http://www.jstor.org/stable/j.ctt183p6gn.
Gerez, Lucas, Geng Gao, Anany Dwivedi, and Minas Liarokapis. "A Hybrid, Wearable Exoskeleton Glove Equipped with Variable Stiffness Joints, Abduction Capabilities, and a Telescopic Thumb." *IEEE access* 8 (2020): 173345-58. https://doi.org/10.1109/ACCESS.2020.3025273.
Goodchild, Philip. *Deleuze and Guattari an Introduction to the Politics of Desire.* Theory, Culture & Society. London: SAGE, 1996.
Gray, Chantelle, Aragorn Eloff, Ananya Roy Pratihar, and Saswat Samay Das. "Fabulation In a time Of algorithmic Ecology: Making The future Possible Again." 105-33. Switzerland: Springer International Publishing AG, 2022.
Grechuta, Klaudia, Jelena Guga, Giovanni Maffei, Belen Rubio Ballester, and Paul F. M. J. Verschure. "Visuotactile Integration Modulates Motor Performance in a Perceptual Decision-Making Task." *Scientific Reports* 7, no. 1 (2017/06/13 2017): 3333. https://doi.org/10.1038/s41598-017-03488-0. https://doi.org/10.1038/s41598-017-03488-0.
Green, Scott A., Mark Billinghurst, XiaoQi Chen, and J. Geoffrey Chase. "Human-Robot Collaboration: A Literature Review and Augmented Reality Approach in Design." *International journal of advanced robotic systems* 5, no. 1 (2008): 1-18. https://doi.org/10.5772/5664.
Grosz, E. A. *Becomings : Explorations in Time, Memory, and Futures.* Ithaca: Cornell University Press, 1999.
———. *The Strange Detours of Sublimation : Psychoanalysis, Homosexuality and Art.* Woolloomooloo N.S.W: Artspace, 1997.
Guattari, F., S. Lotringer, and F. Dosse. *Chaosophy: Texts and Interviews 1972-1977.* MIT Press, 2009. https://books.google.com.au/books?id=kfgkAQAAIAAJ.
Guattari, Félix. *Chaosmosis and Ethico-Aesthetic Paradigm.* Translated by Paul Bains; Julian Pefanis. Sydney, Australia: Power Institute Foundation for Arts & Visual Culture, 2006.
———. *Guattari Schizoanalytic Cartographies.* Northfold, UK: Bloomsbury Publishing Plc, 2013.
———. *The Machinic Unconscious : Essays in Schizoanalysis.* Semiotext(E) Foreign Agents Series. Los Angeles, CA: Semiotexte, 2011.
———. "To Have Done with the Massacre of the Body." https://1000littlehammers.files.wordpress.com/2010/02/guattari_massacre_body_screen.pdf.
Guattari, Félix. *Lines of Flight : For Another World of Possibilities.* Impacts. London: Bloomsbury Academic, an imprint of Bloomsburg Publishing Pl., 2016.
———. *Molecular Revolution : Psychiatry and Politics.* Peregrine Books. Harmondsworth, Middlesex, England ;: Penguin, 1984.
———. *Psychoanalysis and Transversality Texts and Interview 1955-1971.* Translated by Ames Hodges. United States of America: Semiotext(e), 2015.
———. *The Three Ecologies.* Bloomsbury Revelations. Bloomsbury Revelations edition. ed. London: Bloomsbury, 2014.
Guattari, Félix; Genosko, Gary. *The Guattari Reader.* Blackwell Readers. Cambridge, Mass: Blackwell Publishers, 1996.
Guattari, Suely Rolnik; Félix. *Molecular Revolution in Brazil.* Translated by Karel Clapshow; Brian Holmes. 2008 ed. Vol. 1: Semiotext(e), 2008.
Guggenheim, Jacob, Rachel Hoffman, Hanjun Song, and H. Harry Asada. "Leveraging the Human Operator in the Design and Control of Supernumerary Robotic Limbs." *IEEE robotics and automation letters* 5, no. 2 (2020): 2176-83. https://doi.org/10.1109/LRA.2020.2970948.
Hammond Iii, Frank L., Faye Wu, and H. Harry Asada. "Variable Stiffness Pneumatic Structures for Wearable Supernumerary Robotic Devices." Cham, 2018.
Hansen, Mark B. N. *Bodies in Code Interfaces with Digital Media.* New York ;: Routledge, 2006.

Hao, Zhou, Alireza Mohammadi, Denny Oetomo, and Gursel Alici. "A Novel Monolithic Soft Robotic Thumb for an Anthropomorphic Prosthetic Hand." *IEEE robotics and automation letters* 4, no. 2 (2019): 602-09. https://doi.org/10.1109/LRA.2019.2892203.
Haraway, Donna. "Anthropocene, Capitalocene, Plantationocene, Chthulucene: Making Kin." *Environmental Humanities* 6, no. 1 (2015): 159-65. https://doi.org/10.1215/22011919-3615934.
———. *Simians, Cyborgs, and Women.* New York: Routledge, 2013. doi:10.4324/9780203873106.
Haraway, Donna J. *Primate Visions.* New York: Routledge, 2013. doi:10.4324/9780203421918.
Hauptmann, Deborah, and Warren Neidich. *Cognitive Architecture : From Bio-Politics to Noo-Politics ; Architecture & Mind in the Age of Communication and Information.* Delft School of Design Series on Architecture and Urbanism ; 6. Rotterdam: 010 Publishers, 2010.
Hayes, Caroline C., and Christopher A. Miller. *Human-Computer Etiquette: Cultural Expectations and the Design Implications They Place on Computers and Technology.* Supply Chain Integration. London: Auerbach Publications, 2011. doi:10.1201/b10420.
Heidegger, Martin. *The Question Concerning Technology and Other Essays.* Harper Torchbooks ; Tb 1969. Paperback ed. ed. New York: Harper & Row, 1977.
Henry Somers-Hall, Jeffrey A. Bell, James Williams. *A Thousand Plateaus And philosophy.* Edited by Jeffrey A. Bell Henry Somers-Hall, James Williams. Edinburgh University Press, 2018.
Herzogenrath, Bernd. *Deleuze/Guattari & Ecology.* Basingstoke [England] ;: Palgrave Macmillan, 2009.
Heter, Storm. "Sartre's Political Philosophy." In *Internet Encyclopedia of Philosophy*, East Stroudsburg University, 2024. https://iep.utm.edu/sartre-p/#:~:text=Sartre's%20dialectical%20theory%20of%20society,animating%20principle%20of%20human%20history.
Holland, Eugene W. *Deleuze and Guattari's a Thousand Plateaus a Reader's Guide.* Reader's Guides. New York: Bloomsbury Academic, 2013.
Hoopes, James. *Peirce on Signs: Writings on Semiotic by Charles Sanders Peirce.* The University of North Carolina Press, 2014. doi:10.5149/9781469616810_hoopes.
Hörl, Erich Heinrich, and Arne de Boever. "Prostheses of Desire: On Bernard Stiegler's New Critique of Projection." 2014.
Howells, Christina, Stephen Barker, Richard Beardsworth, Miguel De Beistegui, Patrick Crogan, Martin Crowley, Oliver Davis*, et al. Stiegler and Technics.* Critical Connections : Crco. Edinburgh: Edinburgh University Press, 2022. doi:10.1515/9780748677030.
Hu, Yuhan, Sang-Won Leigh, and Pattie Maes. "Hand Development Kit: Soft Robotic Fingers as Prosthetic Augmentation of the Hand." 2017.
Hubatschke, Christoph. "How to Dance with Robots." In *Machinic Assemblages of Desire*, edited by Paulo de Assis and Paolo Giudici. Deleuze and Artistic Research 3, 209-22: Leuven University Press, 2021.
Hui, Yuk. *On the Existence of Digital Objects.* Electronic Mediations ; 48. Minneapolis: University of Minnesota Press, 2016.
Hui, Yuk, and Louis Morelle. "A Politics of Intensity: Some Aspects of Acceleration in Simondon and Deleuze." *Deleuze and Guattari Studies* 11, no. 4 (2017): 498-517. https://doi.org/10.3366/dls.2017.0282.
Hussain, I., G. Salvietti, M. Malvezzi, and D. Prattichizzo. "Design Guidelines for a Wearable Robotic Extra-Finger." Paper presented at the 2015 IEEE 1st International Forum on Research and Technologies for Society and Industry Leveraging a better tomorrow (RTSI), 16-18 Sept. 2015 2015.
Hussain, Irfan, Muddasar Anwar, Zubair Iqbal, Rajkumar Muthusamy, Monica Malvezzi, Lakmal Seneviratne, Dongming Gan, Federico Renda, and Domenico Prattichizzo. "Design and Prototype of Supernumerary Robotic Finger (Srf) Inspired by Fin Ray® Effect for Patients Suffering from Sensorimotor Hand Impairment." 2019.

Hussain, Irfan, Leonardo Meli, Claudio Pacchierotti, and Domenico Prattichizzo. "A Soft Robotic Supernumerary Finger and a Wearable Cutaneous Finger Interface to Compensate the Missing Grasping Capabilities in Chronic Stroke Patients." 2017.
Hussain, Irfan, Leonardo Meli, Claudio Pacchierotti, Gionata Salvietti, and Domenico Prattichizzo. "Vibrotactile Haptic Feedback for Intuitive Control of Robotic Extra Fingers." 2015.
Hussain, Irfan, and Domenico Prattichizzo. *Augmenting Human Manipulation Abilities with Supernumerary Robotic Limbs.* Biosystems & Biorobotics, 26. 1st ed. 2020. ed. Cham: Springer International Publishing, 2020. doi:10.1007/978-3-030-52002-1.
———. "Compensating Hand Function in Chronic Stroke Patients through the Supernumerary Robotic Finger." Biosystems & Biorobotics, 25-38. Switzerland: Springer International Publishing AG, 2020.
Hussain, Irfan, Gionata Salvietti, Leonardo Meli, Claudio Pacchierotti, David Cioncoloni, Simone Rossi, and Domenico Prattichizzo. "Using the Robotic Sixth Finger and Vibrotactile Feedback for Grasp Compensation in Chronic Stroke Patients." 2015.
Hussain, Irfan, Gionata Salvietti, Giovanni Spagnoletti, Monica Malvezzi, David Cioncoloni, Simone Rossi, and Domenico Prattichizzo. "A Soft Supernumerary Robotic Finger and Mobile Arm Support for Grasping Compensation and Hemiparetic Upper Limb Rehabilitation." *Robotics and autonomous systems* 93 (2017): 1-12. https://doi.org/10.1016/j.robot.2017.03.015.
Hussain, Irfan, Gionata Salvietti, Giovanni Spagnoletti, and Domenico Prattichizzo. "The Soft-Sixthfinger: A Wearable Emg Controlled Robotic Extra-Finger for Grasp Compensation in Chronic Stroke Patients." *IEEE robotics and automation letters* 1, no. 2 (2016): 1000-06. https://doi.org/10.1109/LRA.2016.2530793.
Hussain, Irfan, Emiliano Santarnecchi, Andrea Leo, Emiliano Ricciardi, Simone Rossi, and Domenico Prattichizzo. "A Magnetic Compatible Supernumerary Robotic Finger for Functional Magnetic Resonance Imaging (Fmri) Acquisitions: Device Description and Preliminary Results." Paper presented at the IEEE Int Conf Rehabil Robot, United States, 2017.
Hussain, Irfan, Giovanni Spagnoletti, Gionata Salvietti, and Domenico Prattichizzo. "An Emg Interface for the Control of Motion and Compliance of a Supernumerary Robotic Finger." *Frontiers in neurorobotics* 10 (2016): 18-18. https://doi.org/10.3389/fnbot.2016.00018.
———. "Toward Wearable Supernumerary Robotic Fingers to Compensate Missing Grasping Abilities in Hemiparetic Upper Limb." *The International journal of robotics research* 36, no. 13-14 (2017): 1414-36. https://doi.org/10.1177/0278364917712433.
Hynes, Maria. "The Ethico-Aesthetics of Life: Guattari and the Problem of Bioethics." *Environment and planning. A* 45, no. 8 (2013): 1929-43. https://doi.org/10.1068/a45152.
Ihrke, Chris A. Bridgwater, Lyndon Platt, Robert Wampler, II, Charles W. Goza, S. Michael. *Robotic Thumb Assembly*. https://ntrs.nasa.gov/citations/20140001886: NTRS- NASA, 2014.
Iliadis, Andrew. "Informational Ontology: The Meaning of Gilbert Simondon' S Concept of Individuation." *communication +1* 2 (09/08 2013). https://doi.org/10.7275/R59884XW.
———. "A New Individuation: Deleuze's Simondon Connection." *MediaTropes* IV (11/01 2013): 83-100.
Ishida, Ryuya, Leonardo Meli, Yoshihiro Tanaka, Kouta Minamizawa, and Domenico Prattichizzo. "Sensory-Motor Augmentation of the Robot with Shared Human Perception." 2018.
Jan, Slaby ; Philipp, Haueis ; Suparna, Choudhury. "Neuroscience as Applied Hermeneutics: Towards a Critical Neuroscience of Political Theory." 58-81: Routledge, 2012.
John Stuart Mill, John Stuart. "Of the Liberty of Thought and Discussion." New Zealand: Floating Press, The, 2017.
Johnston, John. "Computer Fictions: Narratives of the Machinic Phylum." *Journal of the Fantastic in the Arts* 8, no. 4 (32) (1997): 443-63. http://www.jstor.org.ezproxy.library.sydney.edu.au/stable/43308313.
Jolles, Marjorie. "Between Embodied Subjects and Objects: Narrative Somaesthetics." *Hypatia* 27, no. 2 (2012): 301-18. https://doi.org/10.1111/j.1527-2001.2011.01262.x.

"Jouissance." 2Oxford University Press, 2018.
Kaji-O'Grady, Sandra, and Chris Smith. *Laboratory : Speaking of Science and Its Architecture.* Cambridge, Massachusetts: The MIT Press, 2019.
Kalckert, Andreas, and H. Henrik Ehrsson. "The Moving Rubber Hand Illusion Revisited: Comparing Movements and Visuotactile Stimulation to Induce Illusory Ownership." *Consciousness and Cognition* 26 (2014/05/01/ 2014): 117-32. https://doi.org/https://doi.org/10.1016/j.concog.2014.02.003. https://www.sciencedirect.com/science/article/pii/S1053810014000336.
Kalckert, Andreas, and H. Henrik Ehrsson. "Moving a Rubber Hand That Feels Like Your Own: A Dissociation of Ownership and Agency." *Frontiers in human neuroscience* 6, no. 2012 (2012): 40-40. https://doi.org/10.3389/fnhum.2012.00040.
Kaplan, Jerry. *Artificial Intelligence : What Everyone Needs to Know.* What Everyone Needs to Know. New York: Oxford University Press, 2020.
Katic, D., and M. Vukobratovic. *Intelligent Control of Robotic Systems.* Intelligent Systems, Control and Automation: Science and Engineering, 25. 1st ed. 2003. ed. Dordrecht: Springer Netherlands, 2003. doi:10.1007/978-94-017-0317-8.
Keating, Thomas P. "An Ethology of Technics- Concepts and Experiments with Technological Affects." Doctor of Philosophy, University of Bristol, 2017. https://www.academia.edu/39969526/An_Ethology_of_Technics_Concepts_and_Experiments_with_Technological_Affects.
Kickasola, Joseph G. "Semiotics and Semiology." 457-69: Routledge, 2009.
Kieliba, Paulina, Danielle Clode, Roni O. Maimon-Mor, and Tamar R. Makin. "Robotic Hand Augmentation Drives Changes in Neural Body Representation." *Science robotics* 6, no. 54 (2021). https://doi.org/10.1126/scirobotics.abd7935.
Kivell, Tracy L., Pierre Lemelin, Brian G. Richmond, and Daniel Schmitt. *The Evolution of the Primate Hand: Anatomical, Developmental, Functional, and Paleontological Evidence.* Developments in Primatology: Progress and Prospects. New York, NY: Springer New York, 2016. doi:10.1007/978-1-4939-3646-5.
———. "On Primitiveness, Prehensility, And opposability Of the primate Hand: The contributions Of frederic Wood Jones And john Russell Napier." Developments in Primatology: Progress and Prospects, 5-13. United States: Springer New York, 2016.
Koh, Jeffrey T. K. V., Belinda J. Dunstan, David Silvera-Tawil, and Mari Velonaki. *Cultural Robotics: First International Workshop, Cr 2015, Held as Part of Ieee Ro-Man 2015, Kobe, Japan, August 31, 2015. Revised Selected Papers.* Lncs Sublibrary. Sl 7, Artificial Intelligence. Vol. 9549, Cham: Springer International Publishing AG, 2016.
Kuisel, Richard F. "Anti-Americanism in Retreat: Jack Lang, Cultural Imperialism, and the Anti-Anti-Americans." 45-98. Princeton: Princeton University Press, 2011.
Lacan, Jacques. *The Other Side of Psychoanalysis.* The Seminar of Jacques Lacan ; Bk. 17. New York ;: W.W. Norton, 2007.
Lacan, Jacques, and Bruce Fink. *Transference.* The Seminar of Jacques Lacan ; Book Viii. English edition. ed. Cambridge, UK ;: Polity, 2015.
Lacan, Jacques, and Cormac Gallagher. *Family Complexes in the Formation of the Individual.* Place of publication not identified: [Antony Rowe], 2002.
Lacan, Jacques, and Jacques-Alain Miller. *The Psychoses.* Seminar of Jacques Lacan. Bk. 3, 1955-1956. London ;: Taylor & Francis, 2013. doi:10.4324/9781315800189.
Lacan, Jaques. *The Object Relation: The Seminar of Jacques Lacan, Book Iv.* Translated by Adrian Price. Edited by 1st. Polity, 2021.
Landa, Manuel de. "The Machinic Phylum." Essay, *Technonomorphica*. (1997). https://v2.nl/archive/articles/the-machinic-phylum.
Lane, Chris. "Robotic 'Third Thumb' Use Can Alter Brain Representation of the Hand." *UCL News* (https://www.ucl.ac.uk/news/2021/may), 2024.

https://www.ucl.ac.uk/news/2021/may/robotic-third-thumb-use-can-alter-brain-representation-hand.
"Robotic 'Third Thumb' Use Can Alter Brain Representation of the Hand." University College London, 2021, 2022, https://www.ucl.ac.uk/news/2021/may/robotic-third-thumb-use-can-alter-brain-representation-hand.
Lane, Richard J. *Fifty Key Literary Theorists.* New York, N.Y: Routledge, 2006. doi:10.4324/9780203441428.
Laplanche, Jean. *The Language of Psychoanalysis.* Boca Raton, FL: Routledge, an imprint of Taylor and Francis, 2018.
Lapworth, Andrew. "Gilbert Simondon and the Technical Mentalities and Transindividual Affects of Art-Science." *Body & society* 26, no. 1 (2020): 107-34. https://doi.org/10.1177/1357034X19882750.
Larsen, Lars Bang, Suely Rolnik, and Lygia Clark. "Suely Rolnik on Lygia Clark." *Afterall* 15, no. 15 (2007): 24-34. https://doi.org/10.1086/aft.15.20711637.
Latour, Bruno, and Peter Weibel. "Making Things Public: Atmospheres of Democracy." (2005).
Leach, Neil. "Digital Tool Thinking : Object Oriented Ontology Versus New Materialism." 2016.
Lee, J., L. Yu, L. Derbier, and H. S. Stuart. "Assistive Supernumerary Grasping with the Back of the Hand." Paper presented at the 2021 IEEE International Conference on Robotics and Automation (ICRA), 30 May-5 June 2021 2021.
Leibniz, Gottfried Wilhelm. *The Monadology.* Translated by Robertal Latta. www.plato-philosophy.org: http://home.datacomm.ch/kerguelen/monadology/printable.html, 1898. https://www.plato-philosophy.org/wp-content/uploads/2016/07/The-Monadology-1714-by-Gottfried-Wilhelm-LEIBNIZ-1646-1716.pdf.
Leigh, Sang-won, and Pattie Maes. "Body Integrated Programmable Joints Interface." Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems, San Jose, California, USA, Association for Computing Machinery, 2016.
Leigh, Sang-won, Kush Parekh, Timothy Denton, William Peebles, Magnus Johnson, and Pattie Maes. "Morphology Extension Kit: A Modular Robotic Platform for Customizable and Physically Capable Wearables." Paper presented at the Conference on Human Factors in Computing Systems, 2017.
Leroi-Gourhan, André. *Gesture and Speech.* Cambridge, Mass: MIT Press, 1993.
Levy, Kenneth N., and J. Wesley Scala. "Transference, Transference Interpretations, and Transference-Focused Psychotherapies." *Psychotherapy (Chicago, Ill.)* 49, no. 3 (2012): 391-403. https://doi.org/10.1037/a0029371.
Liang, Caleb, Yen-Tung Lee, Wen-Yeo Chen, and Hsu-Chia Huang. "Body-as-Subject in the Four-Hand Illusion." *Frontiers in psychology* 9 (2018): 1710-10. https://doi.org/10.3389/fpsyg.2018.01710.
Liao, Ziyu, Bai Chen, Tianzuo Chang, Qian Zheng, Keming Liu, and Junnan Lv. "A Human Augmentation Device Design Review: Supernumerary Robotic Limbs." *Industrial robot* 50, no. 2 (2023): 256-74. https://doi.org/10.1108/IR-03-2022-0079.
Lindberg, Susanna. "Being with Technique–Technique as Being-With: The Technological Communities of Gilbert Simondon." *Continental philosophy review* 52, no. 3 (2019): 299-310. https://doi.org/10.1007/s11007-019-09466-9.
Lindblom, Jessica. "Minding the Body: Interacting Socially through Embodied Action." 2007.
Liu, Hongyi, and Lihui Wang. "Gesture Recognition for Human-Robot Collaboration: A Review." *International Journal of Industrial Ergonomics* 68 (2018): 355-67. https://doi.org/10.1016/j.ergon.2017.02.004.
Liu, Sicong, Yuming Zhu, Zicong Zhang, Zhonggui Fang, Jiyong Tan, Jing Peng, Chaoyang Song, H. Harry Asada, and Zheng Wang. "Otariidae-Inspired Soft-Robotic Supernumerary Flippers by Fabric Kirigami and Origami." *IEEE/ASME transactions on mechatronics* 26, no. 5 (2021): 2747-57. https://doi.org/10.1109/TMECH.2020.3045476.

Liu, Yuan, Shuaifei Huang, Zhuang Wang, Fengrui Ji, and Dong Ming. "Functional Reorganization after Four-Week Brain–Computer Interface-Controlled Supernumerary Robotic Finger Training: A Pilot Study of Longitudinal Resting-State Fmri." *Frontiers in neuroscience* 15 (2022): 766648-48. https://doi.org/10.3389/fnins.2021.766648.

Liu, Yuan, Zhuang Wang, Shuaifei Huang, Wenjie Wang, and Dong Ming. "Eeg Characteristic Investigation of the Sixth-Finger Motor Imagery and Optimal Channel Selection for Classification." *Journal of neural engineering* 19, no. 1 (2022): 16001. https://doi.org/10.1088/1741-2552/ac49a6.

Liu, Yuan, Bo Zeng, Li Jiang, Hong Liu, and Ming Dong. "Quantitative Investigation of Hand Grasp Functionality: Thumb Grasping Behavior Adapting to Different Object Shapes, Sizes, and Relative Positions." [In English]. *Applied Bionics and Biomechanics* 2021 (2021

2021-11-28 2021). https://doi.org/https://doi.org/10.1155/2021/2640422. http://ezproxy.library.usyd.edu.au/login?url=https://www.proquest.com/scholarly-journals/quantitative-investigation-hand-grasp/docview/2603591119/se-2

https://sydney.alma.exlibrisgroup.com/openurl/61USYD_INST/61USYD_INST:sydney?genre=article&issn=11762322&title=Quantitative+Investigation+of+Hand+Grasp+Functionality%3A+Thumb+Grasping+Behavior+Adapting+to+Different+Object+Shapes%2C+Sizes%2C+and+Relative+Positions&volume=2021&issue=&date=2021&atitle=Quantitative+Investigation+of+Hand+Grasp+Functionality%3A+Thumb+Grasping+Behavior+Adapting+to+Different+Object+Shapes%2C+Sizes%2C+and+Relative+Positions&spage=&sid=ProQ%3Asciencejournals&author=Liu.

"Plasticity." Institute of Cognitive Neuroscience, University College London, 2023, accessed Sep 2023, 2023, https://www.ucl.ac.uk/icn/plasticity.

Lotringer, Sylvère, Chet Wiener, and Emily Wittman. *Soft Subversions: Texts and Interviews 1977--1985.* Semiotext(E), 2009.

Louis Cohen, Lawrence Manion, Keith Morrison. *Research Methods in Education.* Oxon, Uk: Routledge, 2018.

Lowy, Michael. "A New Type of Party: The Brazilian Pt." *Latin American perspectives* 14, no. 4 (1987): 453-64. https://doi.org/10.1177/0094582X8701400405.

Lush, P., V. Botan, R. B. Scott, A. K. Seth, J. Ward, and Z. Dienes. "Trait Phenomenological Control Predicts Experience of Mirror Synaesthesia and the Rubber Hand Illusion." *Nature Communications* 11, no. 1 (2020/09/25 2020): 4853. https://doi.org/10.1038/s41467-020-18591-6. https://doi.org/10.1038/s41467-020-18591-6.

Lush, P., and A. K. Seth. "Reply To: No Specific Relationship between Hypnotic Suggestibility and the Rubber Hand Illusion." *Nature communications* 13, no. 1 (2022): 563-63. https://doi.org/10.1038/s41467-022-28178-y.

Lush, Peter. "Demand Characteristics Confound the Rubber Hand Illusion." *Collabra. Psychology* 6, no. 1 (2020). https://doi.org/10.1525/collabra.325.

———. "Order Effects in the Rubber Hand Illusion." (2021).

Lushetich, Natasha. *Big Data--a New Medium?* Routledge Studies in Science, Technology and Society. Milton: Taylor & Francis Group, 2020.

Makin, Tamar R., Frederique de Vignemont, and A. Aldo Faisal. "Neurocognitive Barriers to the Embodiment of Technology." *Nature Biomedical Engineering* 1, no. 1 (2017/01/10 2017): 0014. https://doi.org/10.1038/s41551-016-0014. https://doi.org/10.1038/s41551-016-0014.

Makin, Tamar R., Nicholas P. Holmes, and H. Henrik Ehrsson. "On the Other Hand: Dummy Hands and Peripersonal Space." *Behavioural brain research* 191, no. 1 (2008): 1-10. https://doi.org/10.1016/j.bbr.2008.02.041.

Malvezzi, Monica, Zubair Iqbal, Maria Cristina Valigi, Maria Pozzi, Domenico Prattichizzo, and Gionata Salvietti. "Design of Multiple Wearable Robotic Extra Fingers for Human Hand Augmentation." *Robotics (Basel)* 8, no. 4 (2019): 102. https://doi.org/10.3390/robotics8040102.

Mark Hayward, Ghislain Thibault. "Machinic Milieus: Simondon, John Hart and Mechanology." In *Disability History Newsletter*. Fall 2013, 2013. https://www.academia.edu/6320531/Machinic_Milieus_Simondon_John_Hart_and_Mechanology.

Massumi, Brian. *Parables for the Virtual Movement, Affect, Sensation.* Post-Contemporary Interventions. Durham, NC: Duke University Press, 2002.

———. *Politics of Affect.* Ebl. Hoboken: Wiley, 2015.

Mehring, C., M. Akselrod, L. Bashford, M. Mace, H. Choi, M. Blüher, A. S. Buschhoff*, et al.* "Augmented Manipulation Ability in Humans with Six-Fingered Hands." *Nature communications* 10, no. 1 (2019): 2401-01. https://doi.org/10.1038/s41467-019-10306-w.

Meraz, Noel Segura, Hiroshi Shikida, and Yasuhisa Hasegawa. "Auricularis Muscles Based Control Interface for Robotic Extra Thumb." 2017.

Merleau-Ponty, Maurice. *The Structure of Behavior.* Boston: Beacon Press, 1963.

Merleau-Ponty, Maurice, and Donald A. Landes. *Phenomenology of Perception.* Abingdon [England] ;: Routledge, 2012.

Mohan, Rahul, Karin B. Jensen, Valeria I. Petkova, Abishikta Dey, Nadia Barnsley, Martin Ingvar, James H. McAuley, G. Lorimer Moseley, and Henrik H. Ehrsson. "No Pain Relief with the Rubber Hand Illusion." *PloS one* 7, no. 12 (2012): e52400-e00. https://doi.org/10.1371/journal.pone.0052400.

Moxon, Karen A, and Guglielmo Foffani. "Brain-Machine Interfaces Beyond Neuroprosthetics." *Neuron (Cambridge, Mass.)* 86, no. 1 (2015): 55-67. https://doi.org/10.1016/j.neuron.2015.03.036.

Musial, Maciej. *Enchanting Robots: Intimacy, Magic, and Technology.* Social and Cultural Studies of Robots and Ai. Cham: Springer International Publishing AG, 2019.

Nail, Thomas. *Returning to Revolution: Deleuze, Guattari and Zapatismo.* Plateaus. Edinburgh: Edinburgh University Press, 2012. doi:10.3366/j.ctt3fgs00.

Napier, John. "The Evolution of the Hand." *Scientific American* 207, no. 6 (1962): 56-65. http://www.jstor.org.ezproxy.library.sydney.edu.au/stable/24936385.

Napier, John, and Russell H. Tuttle. *Hands.* Princeton Science Library. Revised Edition ed.: Princeton University Press, 2021.

Neidich, Warren. *Warren Neidch Glossary of Cognitive Activism (for a Not So Distant Futre) Archive Books.* 2nd ed., 2019. https://www.academia.edu/42100149/WARREN_NEIDICH_GLOSSARY_OF_COGNITIVE_ACTIVISM_FOR_A_NOT_SO_DISTANT_FUTURE_ARCHIVE_BOOKS.

"Kelly Knox." Altlimbpro, accessed 12/7/2024, 2024, https://thealternativelimbproject.com/in-depth/kelly_knox/.

Nguyen, C. Thi. "Echo Chambers and Epistemic Bubbles." *Episteme* 17, no. 2 (2020): 141-61. https://doi.org/10.1017/epi.2018.32. https://www.cambridge.org/core/article/echo-chambers-and-epistemic-bubbles/5D4AC3A808C538E17C50A7C09EC706F0.

"Oed : Oxford English Dictionary : The Definitive Record of English Language." In *Oxford English dictionary*. Oxford: Oxford University Press. https://www.oed.com/dictionary/architect_n?tab=meaning_and_use#39979088.

Ogden, T. H. "On Potential Space." *International journal of psychoanalysis* 66, no. 2 (1985): 129-41.

Ort, Teddy, Faye Wu, Nicholas Hensel, and Harry Asada. *Supernumerary Robotic Fingers as a Therapeutic Device for Hemiparetic Patients.* 2015. doi:10.1115/DSCC2015-9945.

Parr, Adrian. *The Deleuze Dictionary Revised Edition.* 2nd ed. ed. Edinburgh: Edinburgh University Press, 2010.

Paulina, Kieliba, Clode Danielle, O. Maimon-Mor Roni, and R. Makin Tamar. "Neurocognitive Consequences of Hand Augmentation." Cold Spring Harbor: Cold Spring Harbor Laboratory Press, 2020.

Penrose, Roger, Emanuele Severino, Fabio Scardigli, Ines Testoni, Giuseppe Vitiello, Giacomo Mauro D'Ariano, and Federico Faggin. *Artificial Intelligence Versus Natural Intelligence.* Cham: Springer International Publishing AG, 2022.
Peters, Michael A., and Petar Jandrić. "Posthumanism, Open Ontologies and Bio-Digital Becoming: Response to Luciano Floridi's Onlife Manifesto." *Educational philosophy and theory* 51, no. 10 (2019): 971-80. https://doi.org/10.1080/00131857.2018.1551835.
Prattichizzo, D., M. Malvezzi, I. Hussain, and G. Salvietti. "The Sixth-Finger: A Modular Extra-Finger to Enhance Human Hand Capabilities." Paper presented at the The 23rd IEEE International Symposium on Robot and Human Interactive Communication, 25-29 Aug. 2014 2014.
Prattichizzo, Domenico, Maria Pozzi, Tommaso Lisini Baldi, Monica Malvezzi, Irfan Hussain, Simone Rossi, and Gionata Salvietti. "Human Augmentation by Wearable Supernumerary Robotic Limbs: Review and Perspectives." *Progress in biomedical engineering (Bristol)* 3, no. 4 (2021): 42005. https://doi.org/10.1088/2516-1091/ac2294.
Prattichizzo, Domenico, Gionata Salvietti, Francesco Chinello, and Monica Malvezzi. "An Object-Based Mapping Algorithm to Control Wearable Robotic Extra-Fingers." 2014.
Pridham, Geoffrey. "Southern European Socialism in Transition." 148-67Routledge, 1984.
Protevi, John. "Deleuze and Wexler: Thinking Brain, Body and Affect in Social Context."
Rabellino, Daniela, Paul A. Frewen, Margaret C. McKinnon, and Ruth A. Lanius. "Peripersonal Space and Bodily Self-Consciousness: Implications for Psychological Trauma-Related Disorders." [In English]. Review. *Frontiers in Neuroscience* 14 (2020-December-10 2020). https://doi.org/10.3389/fnins.2020.586605. https://www.frontiersin.org/article/10.3389/fnins.2020.586605.
Racker, Heinrich. *Transference and Counter-Transference.* Routledge, 2018.
Ragland-Sullivan, Ellie, and Mark Bracher. *Lacan and the Subject of Language (Rle: Lacan).* Routledge Library Editions. Lacan ; Volume 3. London: Routledge, 2014. doi:10.4324/9781315851518.
Ramachandran, V. S., D. Rogers-Ramachandran, and S. Cobb. "Touching the Phantom Limb." *Nature (London)* 377, no. 6549 (1995): 489-90. https://doi.org/10.1038/377489a0.
Rantala, Juho. *Anthropomorphism in Social Robotics: Simondon and the Human of Technology.* 2020.
———. *The Notion of Information in Early Cybernetics and in Gilbert Simondon's Philosophy.* 2018.
Read, Jason. *The Micro-Politics of Capital Marx and the Prehistory of the Present.* State University of New York Press, 2003.
Reinhardt, Dagmar, and Lian Loke. "Not What We Think: Sensate Machines for Rewiring." Proceedings of the 9th ACM Conference on Creativity & Cognition, Sydney, Australia, Association for Computing Machinery, 2013.
Reinhardt, Dagmar, Rob Saunders, and Jane Burry. *Robotic Fabrication in Architecture, Art and Design 2016.* Heidelberg: Springer, 2016.
Roberts, Marc. "Capitalism, Psychiatry, and Schizophrenia: A Critical Introduction to Deleuze and Guattari's Anti-Oedipus." *Nursing philosophy* 8, no. 2 (2007): 114-27. https://doi.org/10.1111/j.1466-769X.2007.00306.x.
Rohde, Marieke, Massimiliano Di Luca, and Marc O. Ernst. "The Rubber Hand Illusion: Feeling of Ownership and Proprioceptive Drift Do Not Go Hand in Hand." *PloS one* 6, no. 6 (2011): e21659-e59. https://doi.org/10.1371/journal.pone.0021659.
Rolnik, Suely. "Anthropophagic Subjectivity." (1988). https://www.corner-college.com/udb/cproPe0yM7Suley_Rolnik.pdf.
"Avoiding False Problems: Politics of the Fluid, Hybrid, and Flexible." Journal #25 - Suely Rolnik - Avoiding False Problems: Politics of the Fluid, Hybrid, and Flexible, 2011, accessed 13.07.2021, 2011, https://www.e-flux.com/journal/25/67892/avoiding-false-problems-politics-of-the-fluid-hybrid-and-flexible/.
Rolnik, Suely. "Politics of Flexible Subjectivity: The Event Work of Lygia Clark." In *Antinomies of Art and Culture*, edited by Terry Smith, Okwui Enwezor and Nancy Condee. Modernity, Postmodernity, Contemporaneity, 97-112: Duke University Press, 2008.

———. "Politics of Flexible Subjectivity: The Event Work of Lygia Clark." 97-112. New York, USA: Duke University Press, 2020.
———. "Suely Rolnik: Micropolitical Conceptual Tools for Decolonizing the Unconscious (Notes on Caring and Repairing Life)." In *Classroom*, edited by SAAS FEE Summer Institute of Art, https://www.artandeducation.net/classroom/. www.artandeducation.net, 2020. https://www.artandeducation.net/classroom/video/350702/suely-rolnik-micropolitical-conceptual-tools-for-decolonizing-the-unconscious-notes-on-caring-and-repairing-life.
Rolnik, Suely *Spheres of Insurrection: Notes on Decolonizing the Unconscious.* UK: Polity Press, 2023.
Roseboom, Warrick, and Peter Lush. "Serious Problems with Interpreting Rubber Hand "Illusion" Experiments." *Collabra. Psychology* 8, no. 1 (2022). https://doi.org/10.1525/collabra.32274.
Rossi, Simone, Gionata Salvietti, Francesco Neri, Sara M. Romanella, Alessandra Cinti, Corrado Sinigaglia, Monica Ulivelli*, et al.* "Emerging of New Bioartificial Corticospinal Motor Synergies Using a Robotic Additional Thumb." *Scientific reports* 11, no. 1 (2021): 18487-87. https://doi.org/10.1038/s41598-021-97876-2.
Sai, Ma, Huang Taicheng, Qu Yukun, Chen Xiayu, Zhang Yajie, and Zhen Zonglei. "An Fmri Dataset for Whole-Body Somatotopic Mapping in Humans." *Scientific data* 9, no. 1 (2022): 1-10. https://doi.org/10.1038/s41597-022-01644-4.
Salvietti, G., I. Hussain, D. Cioncoloni, S. Taddei, S. Rossi, and D. Prattichizzo. "Compensating Hand Function in Chronic Stroke Patients through the Robotic Sixth Finger." *IEEE Transactions on Neural Systems and Rehabilitation Engineering* 25, no. 2 (2017): 142-50. https://doi.org/10.1109/TNSRE.2016.2529684.
Salvietti, Gionata, Irfan Hussain, and Domenico Prattichizzo. "The Robotic Sixth Finger: A Wearable Compensatory Tool to Regain Grasping Capabilities in Paretic Hands." Springer Proceedings in Advanced Robotics, 423-37. Cham: Springer International Publishing, 2017.
Samani, Hooman, Elham Saadatian, Natalie Pang, Doros Polydorou, Owen Noel Newton Fernando, Ryohei Nakatsu, and Jeffrey Tzu Kwan Valino Koh. "Cultural Robotics: The Culture of Robotics and Robotics in Culture." *International journal of advanced robotic systems* 10, no. 12 (2013): 400. https://doi.org/10.5772/57260.
Sandry, Eleanor. "Close Encounters with Robots: Re-Evaluating Otherness in Communication." The University of Western Australia, 2011. https://research-repository.uwa.edu.au/en/publications/close-encounters-with-robots-re-evaluating-otherness-in-communica.
Sanfeliu, Isabel. *Karl Abraham : The Birth of Object Relations Theory.* Boca Raton, FL: Routledge, an imprint of Taylor and Francis, 2018.
Sathian, K., and V. S. Ramachandran. *Multisensory Perception : From Laboratory to Clinic.* London, England: Academic Press, 2020.
Sauvagnargues, Anne. *Deleuze and Art.* Translated by Samantha Bankston. Bloomsbury Studies in Continental Philosophy. 1 ed. London: Bloomsbury Academic, 2013. doi:10.5040/9781472547972. http://www.bloomsburycollections.com/book/deleuze-and-art/.
Schettler, Aubrie, Vicente Raja, and Michael L. Anderson. "The Embodiment of Objects: Review, Analysis, and Future Directions." *Frontiers in neuroscience* 13 (2019): 1332-32. https://doi.org/10.3389/fnins.2019.01332.
Schmidgen, Henning. "Inside the Black Box: Simondon's Politics of Technology." *SubStance* 41, no. 3 (2012): 16-31. https://doi.org/10.1353/sub.2012.0024.
Serres, Michel, and Randolph Burks. *Variations on the Body.* Minneapolis: University of Minnesota Press, 2015. doi:10.5749/j.ctt16d696n.
Setiawan, Joga Dharma, Mochammad Ariyanto, M. Munadi, Muhammad Mutoha, Adam Glowacz, and Wahyu Caesarendra. "Grasp Posture Control of Wearable Extra Robotic Fingers with Flex Sensors Based on Neural Network." *Electronics (Basel)* 9, no. 6 (2020): 905. https://doi.org/10.3390/electronics9060905.

Shafti, Ali, Shlomi Haar, Renato Mio, Pierre Guilleminot, and A. Aldo Faisal. "Playing the Piano with a Robotic Third Thumb: Assessing Constraints of Human Augmentation." *Scientific reports* 11, no. 1 (2021): 21375-75. https://doi.org/10.1038/s41598-021-00376-6.
Shiffrin, Seana Valentine. *Speech Matters : On Lying, Morality, and the Law.* Carl G. Hempel Lecture Series ; 4. Course Book ed. Princeton, NJ: Princeton University Press, 2014. doi:10.1515/9781400852529.
———. "A Thinker-Based Approach to Freedom of Speech." 79: Princeton University Press, 2014.
Shikida, H., and Y. Hasegawa. "Hand Space Change after Use of Extra Robotic Thumb." Paper presented at the 2016 International Symposium on Micro-NanoMechatronics and Human Science (MHS), 28-30 Nov. 2016 2016.
Shikida, Hiroshi, Segra-Meraz Noel, and Yasuhisa Hasegawa. "Somatosensory Feedback Improves Operability of Extra Robotic Thumb Controlled by Vestigial Muscles." 2017.
Signorelli, Camilo Miguel. "Can Computers Become Conscious and Overcome Humans?". *Frontiers in robotics and AI* 5 (2018): 121-21. https://doi.org/10.3389/frobt.2018.00121.
Simondon, Gilbert, Cécile Malaspina, and John Rogove. *On the Mode of Existence of Technical Objects.* First edition [in English]. ed. Minneapolis, MN: Univocal Publishing, 2017.
Singh, K. S., and A. Thondiyath. "Design and Analysis of a Soft Bidirectional Bending Actuator for Human-Robot Interaction Applications." Paper presented at the 2019 28th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN), 14-18 Oct. 2019 2019.
Slater, Mel, Daniel Perez-Marcos, H. Henrik Ehrsson, and Maria V. Sanchez-Vives. "Inducing Illusory Ownership of a Virtual Body." *Frontiers in neuroscience* 3, no. 2 (2009): 214-20. https://doi.org/10.3389/neuro.01.029.2009.
Slatman, Jenny. "A Strange Hand: On Self-Recognition and Recognition of Another." *Phenomenology and the Cognitive Sciences* 8, no. 3 (2009/09/01 2009): 321-42. https://doi.org/10.1007/s11097-009-9127-5. https://doi.org/10.1007/s11097-009-9127-5.
Smith, Chris L. *Tranvsersailty Lecture 10*. University of Sydney, 2024.
Smith, Chris L. *Architecture after Deleuze and Guattari.* Deleuze and Guattari Encounters. 1st ed. ed. London: Bloomsbury Academic, 2023. doi:10.5040/9781350168527.
———. *Bare Architecture: A Schizoanalysis.* 1 ed. London: Bloomsbury Publishing Plc, 2017. doi:10.5040/9781350015821.
Sobajima, Masafumi, Yuichiro Sato, Xufeng Wang, and Yasuhisa Hasegawa. "Improvement of Operability of Extra Robotic Thumb Using Tactile Feedback by Electrical Stimulation." 2015.
"Semiotics Vs. Semiology." Bits Blog, 2014, accessed 11/08/2024, 2024, https://community.macmillanlearning.com/t5/bits-blog/semiotics-vs-semiology/ba-p/3989.
Soto van der Plas, Christina, Edgar Miguel Juárez-Salazar, Carlos Gómez Camarena, and David Pavón-Cuéllar. *The Marx through Lacan Vocabulary: A Compass for Libidinal and Political Economies.* Lines of the Symbolic Series. 1 ed. United Kingdom: Routledge, 2022. doi:10.4324/9781003212096.
Stengers, Isabelle. *Cosmopolitics.* Posthumanities ; 9-10. Minneapolis, Minn. ;: University of Minnesota Press, 2010.
———. *The Invention of Modern Science.* Vol. 19: U of Minnesota Press, 2000.
Strickland, Lloyd. *Leibniz's Monadology a New Translation and Guide.* Edinburgh University Press, 2014. http://www.jstor.org.ezproxy.library.sydney.edu.au/stable/10.3366/j.ctt1g0b6qt.
Sue, Best. "Lygia Clark (1920-1988) Bodily Sensation and Affect: Expression as Communion." *Australian and New Zealand journal of art* 6/7, no. 2/1 (2006): 82-104. https://doi.org/10.3316/informit.599298922381641.
Suely Rolnik. *Spheres of Inscurrection: Notes on Decolonizing the Unconscious.* Cambridge, UK: Polity Press, 2023.
Swan, M. "Digital Simondon: The Collective Individuation of Man and Machine." *Platform* 6 (01/01 2015): 46-58.

Talks, TEDx. "Why I Created a Third Thumb | Dani Clode | Tedxvienna." In *TEDxVienna*, https://www.youtube.com/, 2018. https://www.youtube.com/watch?v=UD_LwZD2Kls.
Thomas, Neal. *Becoming-Social in a Networked Age.* Routledge Studies in New Media and Cyberculture. First edition. ed. London: Taylor and Francis, 2018. doi:10.4324/9781315195629.
Tiziani, Lucas, Alexander Hart, Thomas Cahoon, Faye Wu, H. Harry Asada, and Frank L. Hammond. "Empirical Characterization of Modular Variable Stiffness Inflatable Structures for Supernumerary Grasp-Assist Devices." *The International journal of robotics research* 36, no. 13-14 (2017): 1391-413. https://doi.org/10.1177/0278364917714062.
Tong, Yuchuang, and Jinguo Liu. "Review of Research and Development of Supernumerary Robotic Limbs." *IEEE/CAA journal of automatica sinica* 8, no. 5 (2021): 929-52. https://doi.org/10.1109/JAS.2021.1003961.
Trabant, Jürgen. "Louis Hjelmslev: Glossematics as General Semiotics." Topics in Contemporary Semiotics, 89-108. Boston, MA: Springer US.
Trevor-Roper, H. R. "Fernand Braudel, the Annales, and the Mediterranean." *The Journal of modern history* 44, no. 4 (1972): 468-79. https://doi.org/10.1086/240838.
Tsakiris, Manos, and Patrick Haggard. "The Rubber Hand Illusion Revisited: Visuotactile Integration and Self-Attribution." *Journal of experimental psychology. Human perception and performance* 31, no. 1 (2005): 80-91. https://doi.org/10.1037/0096-1523.31.1.80.
Tucker, Ian M., and Lewis Goodings. "Sensing Bodies and Digitally Mediated Distress: Serres, Simondon, and Social Media." *The senses & society* 9, no. 1 (2014): 55-71. https://doi.org/10.2752/174589314X13834112761047.
Tuinen, Sjoerd van, and Niamh McDonnell. *Deleuze and the Fold: A Critical Reader.* London: Palgrave Macmillan UK, 2010. doi:10.1057/9780230248366.
Umezawa, Kohei, Yuta Suzuki, Gowrishankar Ganesh, and Yoichi Miyawaki. "Bodily Ownership of an Independent Supernumerary Limb: An Exploratory Study." *Scientific reports* 12, no. 1 (2022): 2339-39. https://doi.org/10.1038/s41598-022-06040-x.
Villalba, Joaquín, Fernando A. Navarro, and Francisco Cortés. "Origin, History, and Meanings of the Word Transmission." *Microbiology spectrum* 5, no. 6 (2017). https://doi.org/10.1128/microbiolspec.MTBP-0004-2016.
Villani, Arnaud. "The Insistence of the Virtual in Science and the History of Philosophy." University of Minnesota Press, 2010.
Voss, Daniela. "Invention and Capture: A Critique of Simondon." *Culture, theory and critique* 60, no. 3-4 (2019): 279-99. https://doi.org/10.1080/14735784.2019.1679652.
Vysocky, Ales, and Petr Novak. "Human - Robot Collaboration in Industry." *MM Science Journal* 2016-, no. 2 (2016): 903-06. https://doi.org/10.17973/MMSJ.2016_06_201611.
Walters, Michael. "The Design Space for Robot Appearance and Behaviour for Social Robot Companions." (01/01 2008).
Wang, Mian, Gujie Mi, Di Shi, Nicole Bassous, Daniel Hickey, and Thomas J. Webster. "Nanotechnology and Nanomaterials for Improving Neural Interfaces." *Advanced functional materials* 28, no. 12 (2018): 1700905-n/a. https://doi.org/10.1002/adfm.201700905.
Weinstein, James. "Seana Shiffrin's Thinker-Based Theory of Free Speech: Elegant and Insightful, but Will It Work in Practice? (Response to Article in This Issue, P. 283) (Symposium: Individual Autonomy and Free Speech)." *Constitutional commentary* 27, no. 2 (2011): 385.
Wichmann, Felix A., and N. Jeremy Hill. "The Psychometric Function: I. Fitting, Sampling, and Goodness of Fit." *Perception & Psychophysics* 63, no. 8 (2001/11/01 2001): 1293-313. https://doi.org/10.3758/BF03194544. https://doi.org/10.3758/BF03194544.
Williams, Mary-Anne. *Robot Social Intelligence.* Vol. 7621, 2012. doi:10.1007/978-3-642-34103-8_5.
Williford, Kenneth, Daniel Bennequin, Karl Friston, and David Rudrauf. "The Projective Consciousness Model and Phenomenal Selfhood." *Frontiers in psychology* 9 (2018): 2571-71. https://doi.org/10.3389/fpsyg.2018.02571.

Wilmer, S. E. "Deleuze, Beckett, and the Art of Multiplicity." *New theatre quarterly* 38, no. 2 (2022): 186-94. https://doi.org/10.1017/S0266464X22000070.

Winnicott, Donald W. "Transitional Objects and Transitional Phenomena: A Study of the First Not-Me Possession1." In *The Collected Works of D. W. Winnicott: Volume 4, 1952-1955*, edited by Lesley Caldwell and Helen Taylor Robinson, 0: Oxford University Press, 2016.

Wu, F. Y., and H. H. Asada. "“Hold-and-Manipulate” with a Single Hand Being Assisted by Wearable Extra Fingers." Paper presented at the 2015 IEEE International Conference on Robotics and Automation (ICRA), 26-30 May 2015 2015.

Wu, Faye, and Harry Asada. "Bio-Artificial Synergies for Grasp Posture Control of Supernumerary Robotic Fingers." (07/22 2014). https://doi.org/10.15607/RSS.2014.X.027.

———. "Supernumerary Robotic Fingers: An Alternative Upper-Limb Prosthesis." *ASME 2014 Dynamic Systems and Control Conference, DSCC 2014* 2 (10/22 2014). https://doi.org/10.1115/DSCC2014-6017.

Wu, Faye Y., and H. Harry Asada. "Decoupled Motion Control of Wearable Robot for Rejecting Human Induced Disturbances." 2018.

———. "Implicit and Intuitive Grasp Posture Control for Wearable Robotic Fingers: A Data-Driven Method Using Partial Least Squares." *IEEE transactions on robotics* 32, no. 1 (2016): 176-86. https://doi.org/10.1109/TRO.2015.2506731.

Wu, Faye Y., and Harry H. Asada. "Supernumerary Robotic Fingers: An Alternative Upper-Limb Prosthesis." 2012.

Yang, Bo, Jian Huang, Xinxing Chen, Caihua Xiong, and Yasuhisa Hasegawa. "Supernumerary Robotic Limbs: A Review and Future Outlook." *IEEE transactions on medical robotics and bionics* 3, no. 3 (2021): 623-39. https://doi.org/10.1109/TMRB.2021.3086016.

Young, Eugene B., Gary Genosko, and Janell Watson. *The Deleuze and Guattari Dictionary.* Bloomsbury Philosophy Dictionaries. London ;: Bloomsbury Academic, 2013.

Young, Richard W. "Evolution of the Human Hand: The Role of Throwing and Clubbing." *Journal of anatomy* 202, no. 1 (2003): 165-74. https://doi.org/10.1046/j.1469-7580.2003.00144.x.

Zarrintaj, Payam, Mohammad Reza Saeb, Seeram Ramakrishna, and Masoud Mozafari. "Biomaterials Selection for Neuroprosthetics." *Current opinion in biomedical engineering* 6 (2018): 99-109. https://doi.org/10.1016/j.cobme.2018.05.003.

Zhu, Yaonan, Takayuki Ito, Tadayoshi Aoyama, and Yasuhisa Hasegawa. "Development of Sense of Self-Location Based on Somatosensory Feedback from Finger Tips for Extra Robotic Thumb Control." *ROBOMECH journal* 6, no. 1 (2019): 1-10. https://doi.org/10.1186/s40648-019-0135-0.

Zhu, Yaonan, Hiroshi Shikida, Tadayoshi Aoyama, and Yasuhisa Hasegawa. "Evaluating Shifted Body Representation and Modified Body Schema Using Extra Robotic Thumb." 2018.

Appendix 1 - Scope and definitions from the introduction

Arborescence

Arborescent refers to a mode of organisation or structure that is hierarchical, centralised, and rigidly stratified, following linear logic and fixed paths. It contrasts with rhizomatic or non-hierarchical models of organisation, which are fluid, interconnected, and decentralised. This term encompasses all the systems that Guattari is very critical of and uses only in the measure in which Guattari refers to them.

Architecture

Architecture here has two definitions. It is commonly understood to mean a form of shelter, characterised by walls, windows, and spatial divisions. A static object is usually a representation of power hegemonies as viewed in commercial architecture, but it is also a reflection of familial life in structures such as domestic settings. Its other meaning relies on the idea that Architecture comes from the proportions of the body; it relates the body to the wider built environment and is the product of politics, social and political structures. In the case of its redefinition is considered by me as an extension of the body in such morphological design, such a in supernumerartly robotics structures where subjectivity is intertwined (subject-object relational interweave) in the roots of all proidcutoin of arhictecture that not only protects the bodies outlines but furthers and gives life forces that expand the very essence of its temporal organic and machinic articulations (techno-subjectivity). The term does not deal with anything other than the habitual thoughts that define architecture and the way it is being considered as an extension of the body and as the 'art of being a subject'.[1190]

[1190] Smith, *Tranvsersailty Lecture 10*.

Assemblages (*Agencements*)

In Félix Guattari's works, especially in collaboration with Gilles Deleuze, the term *assemblage* (*agencement* in French) refers to a dynamic, heterogeneous collection of elements that come together in a temporary, non-hierarchical, and productive relationship. An assemblage is not a fixed structure but a process of interaction between different components—material, social, political, semiotic, and subjective. The key to an assemblage is that it is not bound by rigid organisation but is fluid and capable of creating new connections, producing meaning, and facilitating change. Rolink defines it in the following way in the definition given in *Molecular Revolution in Brazil:* '[a]n assemblage comprises heterogeneous elements, which may be of a biological, social, machinic, gnoseological or imaginary order.'[1191]

Assemblages of enunciation (also known as agents of enunciation)

In Félix Guattari's works, particularly in the texts *Molecular Revolution in Brazil*[1192], The *Machinic Unconscious*[1193], *Psychoanalysis and Transversality*[1194], and *Chaosmosis*[1195], an *assemblage of enunciation* refers to the collective, dynamic processes through which subjectivity, meaning, and expression are produced and transformed. These assemblages consist of interconnected elements—voices, gestures, signs, media, symbols, social structures—that work together to generate and communicate meaning within a specific context.

An assemblage of enunciation differs from traditional, fixed linguistic or psychoanalytic structures because it is not confined to language alone. Instead, it includes the material, social, semiotic, and subjective forces that shape how meaning is produced, circulated, and understood. It is a collective process, not bound to individual expression but emerging through interactions across multiple domains.

[1191] Guattari, *Molecular Revolution in Brazil*, 1, p463.
[1192] Guattari, *Molecular Revolution in Brazil*, 1, p43,469.
[1193] Guattari, *The machinic unconscious : essays in schizoanalysis*, p54.
[1194] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p14.
[1195] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p8-9.

Becoming

Becoming refers to the process of continuous transformation and change, where subjectivities and realities are never fixed or tied to a final identity or phylum but are always evolving 'related to the economy of desire'[1196]. This concept emphasises fluidity, multiplicity, and the crossing of boundaries between established categories (e.g., human/animal, subject/object, or individual/collective) eg. 'The image is carried by a becoming other, ramified in becoming animal, becoming plant, becoming machine and, on occasion, becoming human.'[1197]

Body

Guattari defines the *body* as a machinic assemblage, a dynamic intersection of forces (psychic, social, political, material, semiotic), where subjectivity is produced and transformed. The body is not static but constantly in flux, shaped by interactions with its environment and participating in the processes of desire, power, and communication.[1198] The body is a site for enunciation and resistance, while all its fragments are transcended by the unconscious and its engendered production of subjectivity. The body is an assemblage of the art of objects-subjective reciprocal production and its latent desires. Guattari's concept of the body as an assemblage or a site of interaction offers a new way of understanding how subjectivity is created, not within an isolated individual, but through dynamic relations with technology (more precisely technics), social systems, and environmental forces. This opens up radical possibilities for rethinking how we engage with technology and bodies in the modern world.

Capital

Capital, in Guattari's framework, refers to a system of control that operates not only through economic structures but also through the capture of semiotic, social, and subjective flows. It extends beyond the material economy into how desire, subjectivity, and social relations are

[1196] Guattari, *Molecular Revolution in Brazil*, 1, p463.
[1197] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p95.
[1198] Guattari, *Molecular Revolution in Brazil*, 1, p409-11.

shaped, controlled, and exploited within capitalist systems. Capital functions as a machinic process, constantly reconfiguring reality to reproduce its logic of domination and accumulation. It is also related to the concept of Integrated World Capital (IWC)[1199] as explained in *Molecular Revolution in Brazil* by Guattari and Rolnik.

Coefficient of transversality

The *coefficient of transversality* refers to a system's (whether institutional, social, or psychic) capacity to foster open, non-hierarchical, and dynamic connections across different levels or dimensions. It is a measure of the system's ability to escape rigid, vertical structures of power and authority, promoting instead horizontal, transversal interactions that cut across boundaries and categories.

Guattari introduces this concept to challenge the compartmentalisation of knowledge, authority, and power, advocating instead for a transversal flow of communication and transformation between different fields—such as psychoanalysis, politics, art, and social structures. As Guattari advises, those such as subject-groups who have the wherewithal to understand their own finality and nonsense, and the ability to negotiate the hierarchies of the hegemonic worlds, because they are empowered to do so, display high levels of coefficients of transversality. Guattari suggests '[g]roup-subjects, on the other hand, are defined by coefficients of Transversality that ward off totalities and hierarchies.'[1200] For Guattari, high coefficients of transversality bring in new smoothness and a new social order of connectivity.[1201]

Collective

Guattari critiques the traditional concept of individual subjectivity and proposes the collective as a site of transformation, where new forms of subjectivity are produced through the intersection of various machinic processes, social forces, and desires. Rolnik and Guattari specifically tell us:

[1199] Guattari, *Molecular Revolution in Brazil*, 1, p262-665.
[1200] Guattari, *Psychoanalysis and Transversality Texts and Interview 1955-1971*, p14.
[1201] Guattari, *Molecular Revolution in Brazil*, 1, p417.

> It must be emphasised that here "collective" should not be understood solely in the sense of a social group; it also implies the involvement of a variety of collections of technical objects, flows of matter and energy, incorporeal entities, mathematical or aesthetic idealities, etc.[1202]

A collective of the concrete, real world cut from the more abstract notion of an assemblage that is material and real. It is a constantly evolving assemblage of heterogeneous elements (individuals, machines, desires, and semiotic flows) that interact in a transversal, non-hierarchical manner. Collectives are not rigid or stable; they are dynamic, producing new subjectivities, realities, and relations as they function. This concept emphasises how individuals and groups are interdependent, interconnected, and shaped by shared processes of desire, production, and transformation.

Desire

Desire is a fundamental, productive, unconscious, and highly differentiated force that drives the creation of new subjectivities, social relations, and realities. It's so much more than sexual desire; it is the unformulated power behind subjectivity and transversality. Rather than being a force rooted in *lack* or personal repression (as in classical psychoanalysis), Guattari's concept of desire is expansive and generative. It operates through assemblages and flows, connecting individuals, machines, institutions, and environments in creative and transformative ways. Its flow mobilises and is the cohesive glue that binds assemblages and shapes subjectivities. Desire does not aim for a specific object or fulfilment, but functions through transversal movements across systems, producing change and new arrangements of life via flows of ideas and creative inventions, even before they are formed.

Desire, in Guattari's terms, is inherently collective and social, linked to political and revolutionary movements. It creates multiplicities and disrupts traditional hierarchies, offering a path to new forms of subjectivity and social arrangements.

[1202] Guattari, *Molecular Revolution in Brazil*, 1, p465.

Group therapeutics- subject-group and subjugated group

Guattari distinguishes between two fundamental types of group formations with distinct characteristics under the term group therapeutics:

Subject-group: A subject-group possesses an active, self-determining orientation toward its own existence. It maintains awareness of its finitude and embraces its processual nature rather than seeking eternal identity. Subject-groups are characterised by their ability to manage external determinations and their own internal laws, making them capable of establishing their own goals and desires. They develop their own modes of valorisation, remain open to multiple voices and perspectives, and can articulate their position in relation to power structures. Rather than simply conforming to established norms, subject-groups create new forms of expression and establish innovative connections with the social field. They maintain what Guattari calls a high coefficient of transversality, meaning they can form connections across different domains and resist hierarchical organisation. Subject-groups are also known as *processes of singularization.*

Subjugated group: A subjugated group, by contrast, is passive in relation to external forces that determine its existence. It tends to be manipulated by external determinations and dominated by its own internal law (particularly superego structures). Such groups typically form around established hierarchies, adopt pre-existing modes of subjectivity without questioning them, and serve as instruments for maintaining dominant social orders. The subjugated group often lacks awareness of its own position within power structures and tends to unconsciously reproduce these structures. These groups operate with a low coefficient of transversality, making them more isolated and less able to form connections across different social domains. They often become fixated on their own perpetuation rather than engaging with the possibilities of transformation.

This distinction is not absolute, but rather represents the poles of a continuum along which groups can move. A key aspect of Guattari's political and therapeutic work involved helping subjugated groups transform into subject-groups by increasing their awareness, agency, and transversality.

Machinic (assemblages and processes)

Refers not simply to technological or mechanical objects, but to complex arrangements of heterogeneous elements—human, social, technological, semiotic, biological—that function together to produce specific effects. Unlike mechanical systems, which operate through fixed causality and predetermined outcomes, machinic processes are characterised by their autopoietic potential, their capacity to generate unpredictable bifurcations and to create new realities. Machinic assemblages cut across traditional divides between nature/culture, human/non-human, and material/immaterial. They operate through flows, breaks, and connections rather than static structures, constituting the dynamic fabric of desire, social formations, and subjectivity itself. For Guattari, the machinic dimension is both ontological and processual, always partial and open to mutation, and stands in contrast to signifying structures that attempt to capture and overcede difference.

Paradigm of the third-thumb

A conceptual framework that examines Supernumerary Robotic Fingers (SRFs) not merely as technics of augmentation and additions but as assemblages that catalyse new forms of subjectivity. Unlike the technical field of SRF research that focuses on functionality and design, this paradigm addresses the micropolitical dimensions of these machinic extensions—analysing how they reconfigure desire, affect, perception, and social relations. The third-thumb introduces a heterogeneous element that deterritorialises the normalised body schema, potentially triggering molecular revolutions in how subjectivity is produced and experienced. This paradigm connects technics of augmentation to broader questions of social organisation, economic structures, political resistance, and psychoanalytic understandings of subjectivity, suggesting that even seemingly minor bodily modifications contain potentials for resingularization and creation of new existential territories.

Prosthetic

A term encapsulated within a limited and reductive semiotic framework that positions augmented bodies as deficient or *less than* normative ones. Unlike the conceptual richness of machinic assemblages, prosthetics remain confined to a medical-technical paradigm of substitution and compensation for *lost* functions or limbs. The prosthetic approach treats the body as a closed system that requires repair, rather than as a site of potential becoming and resingularization. This singular, utilitarian understanding reduces complex body-technology relationships to mere functional replacements, overlooking the molecular, affective and subjective dimensions of human-machine encounters. The prosthetic paradigm exemplifies what Guattari might identify as a territorialisation of the body under capitalistic subjectivity—reinforcing normalised conceptions of embodiment rather than opening toward new existential territories and possibilities of deterritorialisation that something like the SRF might enable.

Semiotics and semiology

In contrast to traditional structuralist approaches that reduce all expressive forms to linguistic signification, Guattari develops a more expansive understanding of semiotics. He distinguishes between signifying semiotics (based on language and representation) and a-signifying semiotics (which operate directly on material reality without linguistic mediation). While semiology refers to the study of signs within closed linguistic systems governed by the signifier, Guattari's semiotics encompasses a broader range of expressive modalities—including technical machines, bodies, gestures, rituals, and molecular processes—that produce effects without necessarily passing through representation. This approach refuses the primacy of the linguistic signifier, recognising instead the heterogeneous nature of semiotic components that operate across different ontological registers. For Guattari, semiotics extends beyond human communication into the realm of machinic processes, affective intensities, and existential territories, constituting a key dimension of how subjectivity is produced within social formations.

Subjectivity

Rather than an individual inner essence or psychological interiority, Guattari conceptualises *subjectivity* as a collective and plural production—the 'ensemble of conditions which render possible the emergence of individual and/or collective instances as self-referential existential Territories, adjacent to, or in delimiting relation with an alterity that is itself subjective.'[1203] Subjectivity is always manufactured and modelled by social, technological, semiotic and machinic processes; it is neither a stable structure nor a fixed possession, but an open-ended, heterogeneous assemblage constantly being produced at multiple levels. This production occurs through various components: pre-personal affects, social relations, material environments, language, media, economic forces, and institutional practices. Guattari emphasises that subjectivity has a fundamentally non-human dimension that precedes individual consciousness, with machines of all types (technical, aesthetic, social) participating in its creation. The aim of his schizoanalytic approach is not to interpret subjectivity but to foster processes of resingularization or the 'process of singularization'[1204] that resist the standardising effects of capitalistic subjectivity and enable new forms of existential self-valorisation.

Supernumerary Robotic Finger (SRF)

An augmentative technological device that adds an additional, artificial digit to the human hand. Unlike prosthetics that replace missing body parts, the SRF serves as a supplementary element that enhances the hand's natural capabilities. Operating at the intersection of biological embodiment and machinic augmentation, SRFs function as concrete manifestations of human-machine hybridisation, creating new potentials for interaction with the material world. The ontological significance of SRFs extends beyond their utilitarian function, as they introduce novel configurations of the body schema, potentially triggering shifts in subjectivity, perception, and embodied knowledge. SRFs represent a material instantiation of what Guattari might identify as a machinic heterogenesis—a process through which new assemblages emerge that challenge established categorisations of the human body and conventional distributions of agency between humans and technology.

[1203] Guattari, *Chaosmosis and ethico-aesthetic paradigm*, p9.
[1204] Guattari, *Molecular Revolution in Brazil*, 1, p23.

Techno-subjectivity

A transformative relationship between the technics of integration and subjective experience, particularly in the context of SRF technologies. *Techno-subjectivity* represents the emergent condition where technics of augmentation directly influences how individuals relate to themselves and their contexts. Unlike traditional understandings of technology as external tools controlled by human agency, techno-subjectivity refers to an intrinsic entanglement where technologies become inseparable from our psychoanalytical life and subjective survival.

Techno-subjectivity operates as a pathway to recovering creative desire flows that have been constrained by capitalistic subjectivity, enabling the breaking of social boundaries and dismantling restrictive barriers that have traditionally alienated and disempowered individuals. It functions as a micropolitical force for transformation that doesn't require destructive revolutionary ruptures; instead, it facilitates gradual, grassroots change driven by fundamental desires and ethics, creating smooth transitions rather than abrupt societal fractures.

Through an 'ethico-aesthetic' dimension, techno-subjectivity makes subjectivity receptive to alternative ways of living and relating to various contexts—whether other people, objects, organisms, or broader environments. This receptivity breaks through normative boundaries imposed by capital, dogmatic ideologies, and hegemonic pressures. It creates a multiplier effect on neurocognitive capacities that corrects power imbalances through expanded sensory awareness, enabling deeper forms of relationality and environmental sensitivity, particularly through bodily interfaces like hand augmentation. Techno-subjectivity reconfigures leisure and desire as central components of living, moving beyond utilitarian understandings of technology toward recognition of how technics of integration fundamentally reshapes subjective experience and social organisation.

Importantly, techno-subjectivity implies the influence of broader technological architectures on subjective experience, including built environments, digital infrastructures, and institutional arrangements. The concept does not romanticise technology but positions it as a contextual negotiation that must remain ethically grounded, seeking harmony and reciprocal understanding while acknowledging potential challenges. Crucially, while techno-subjectivity may flourish where basic needs are met, it remains linked to broader struggles for fundamental rights to survival—connecting personal transformation to collective liberation.

This framework offers a nuanced alternative to both technophobic anxiety and uncritical technological utopianism, instead positioning techno-subjectivity as a complex, embodied process with profound implications for how we understand ourselves, relate to others, and organise society.

Territorialisation/deterritorialisation/reterritorialisation

In Guattari's theoretical framework, territorialisation refers to the process by which assemblages organise and stabilise themselves within specific domains. A territory is not merely a physical space but an existential domain that provides consistency and familiarity. Territories establish boundaries, create patterns, and define identities. They can be physical (like a home), psychological (like habitual thought patterns), social (like institutional structures), or cultural (like artistic conventions). Territorialisation creates existential territories where subjectivity can feel "at home" and develop a sense of meaning and purpose.

Deterritorialization is the process by which assemblages break free from established territories, opening themselves to new connections and possibilities. It involves the dissolution of boundaries, the disruption of fixed patterns, and the liberation of elements from their familiar contexts. Deterritorialisation can be relative (when immediately followed by reterritorialisation into another territory) or absolute (when it reaches a plane of immanence or smooth space that is an area of desire and cooperation without immediately reconstituting new territories). Capitalism, for example, functions through the constant deterritorialisation of traditional social codes while simultaneously reterritorialising desire within the framework of the market and private property.

Reterritorialisation is the process of forming new territories after deterritorialisation. It involves establishing new boundaries, creating new patterns, and defining new identities. Reterritorialisation doesn't necessarily return elements to their original territories but often creates new assemblages with different configurations. It can operate as a creative force (generating new possibilities for subjectivity) or as a reactive one (reinstating control through artificial or 'compensatory' territories).

These three processes operate together in a dynamic relationship. For Guattari, they are not merely abstract concepts but concrete mechanisms through which subjectivity and social formations evolve. A key aspect of his political and therapeutic work involved facilitating

productive cycles of de- and reterritorialisation that could liberate desire from constraining territories while avoiding the dangers of uncontrolled deterritorialisation that might lead to psychic collapse or social chaos.

Transversality

A concept central to Guattari's thought that replaces both vertical hierarchies and horizontal impasses with diagonal or crosswise movements across different domains. As an operational tool, transversality enables connections between heterogeneous elements—across institutional structures, social fields, subjective formations, and disciplinary boundaries—without reducing their specificities. Unlike universalising perspectives that subsume differences under unified concepts, transversality preserves and intensifies singularities while creating new configurations of relation. In institutional settings, it refers to maximising communication across different levels and in different directions, countering bureaucratic segmentation. On a theoretical level, it challenges binary oppositions (such as individual versus society, nature versus culture, human versus machine) by tracing lines of connection and mutation that traverse these divides. Transversality is both an analytical method for understanding complex assemblages and a practical approach to fostering new forms of collective subjectivity that resist capitalistic homogenisation.

Appendix 2 - A perspective on the evolution of the human hand

The human hand is a profoundly symbolic mark of a unique and privileged evolutionary and biologically innovative epoch, that of the early hominins and their forebears, such as *Australopithecus* and early modern humans, *Homo sapiens*. The evolutionary relationship between the hand and the brain, as well as the context of their environment, has always been a crucial factor in considering their development. The human hand's dexterity has profoundly impacted the entire planet and the technics that ensued from its conception. Tracey Kivell and Pierre Lemelin have written a book titled *The Evolution of the Primate Hand: Anatomical, Developmental, Functional, and Paleontological Evidence*, 2016[1205]. Pierre Lemelin and Daniel Schmitt contextualise the importance of the hand by arguing 'history is written by the victors'[1206] in their Front Matter and later in a Chapter of this book under the section titled, 'On Primitivness, Prehensibility, and Opposability of the Primate Hand: Contributions of Frederic Wood Jones and John Russel Napier'[1207]. They maintain that our lauding of the hand as somehow an advanced artifact of human evolution is, by the mere fact, a possible fallacy. If any other species had won this biotechnological arms race for the hand and writ their history, they, too, would endow their hands or their equivalent at the apex of the evolutionary precipice. Lemelin and Schmitt contend that dispelling myths about the hand and its level of advancement is all a matter of perspective. Other species achieve spectacular things with their hand equivalents, such as 'pentadactyl mammals (i.e., mammals with five digits or rays)'.[1208] The primates that they refer to have developed very specialised hands that allow them to colonise various strata of the forest canopy. Their evolution has led to the development of specialised hand ontologies for each level in the forest strata to address canopy differentiation. This shows us the advanced character of the hands' development in some primates, which is far beyond the development of the human hand, as explained by Lemelin and Schmitt.

Frederick Wood Jones and John Russel Napier's work has provided us with a unique and longstanding perspective on the nature of hand development. Both physicians and comparative and functional anatomists, amongst their interests in paleoanthropology and anthropology, established

[1205] Tracy L. Kivell et al., *The Evolution of the Primate Hand: Anatomical, Developmental, Functional, and Paleontological Evidence*, Developments in Primatology: Progress and Prospects, (New York, NY: Springer New York, 2016).
[1206] Kivell et al., "On Primitiveness, Prehensility, and Opposability of the Primate Hand: The Contributions of Frederic Wood Jones and John Russell Napier," p5.
[1207] Kivell et al., "On Primitiveness, Prehensility, and Opposability of the Primate Hand: The Contributions of Frederic Wood Jones and John Russell Napier."
[1208] Kivell et al., "On Primitiveness, Prehensility, and Opposability of the Primate Hand: The Contributions of Frederic Wood Jones and John Russell Napier," p6.

the discourse on the primitive nature of the human hand. Lemelin and Schmitt describe Wood Jones and Napier's contribution in this way:

> revolutionary and disruptive ideas. They turned the idea of uniqueness on its head and forced anthropologists to rethink the concept of the human hand as being "special". Wood Jones reminded anthropologists of the primitive nature of the primate hand. Napier picked up on this theme and defined concepts of hand prehension and opposability that hold sway today.[1209]

Le Gros Jones, a mentor to both Wood Jones and Napier, inspired both men to make significant contributions around three themes that circumscribe discussions around the hand today. Those being 'primitiveness, prehensibility, and opposability.'[1210] These will be technical qualities that characterise the use of the hand and its interaction with tools, and they will most definitely be a design standard when fashioning the capabilities of hands with extra augmented fingers.

In his 1962 groundbreaking paper, 'The Evolution of the Hand'[1211], Napier reflects on paleontological discoveries made by L. S. B. Leaky and his wife, Mary. Their 1959 discovery of a million-year-old man-ape, to which they gave the name *Zinjanthropus*, in Olduvai Gorge in Tanganyika, predates any other paleontological sites, which allow the study of the history of hominid anatomy, found with their tools, coeval.[1212] This site enabled the study of the hand with its tools in place, leading to a theory that challenges previous notions of how the human hand's dexterity is essentially determined by the development of cerebral capacity, thereby linking intelligence and hand development in human evolution. The hand of *Zinjanthropus* provides us with the earliest model of how our hands developed, and it is evident that its mapping and developmental structure were well established prior to our cranial expansion, that is, before cerebral growth and the development of intelligence. Therefore, the discovery of *Zinjanthropus* suggests that the coupling of brain development (cerebral expansion) and the evolution of the human hand is not correlated. The shape and form of the hands evolved before, not after, the development of the brain. As Napier recollects from an earlier paper

> It is a matter of considerable surprise to many to learn that the human hand, which can achieve so much in the field of creative art, communicate such subtle shades of meaning, and upon which the pre-eminence of *Homo sapiens* in the world of animals so largely depends, should constitute in a structural sense, one of the most primitive and generalized parts of the human body.[1213]

[1209] Kivell et al., "On Primitiveness, Prehensility, and Opposability of the Primate Hand: The Contributions of Frederic Wood Jones and John Russell Napier," p11.
[1210] Kivell et al., "On Primitiveness, Prehensility, and Opposability of the Primate Hand: The Contributions of Frederic Wood Jones and John Russell Napier," p6.
[1211] Napier, "The Evolution of the Hand."
[1212] Napier, "The Evolution of the Hand," p56.
[1213] Napier, "The Evolution of the Hand," p56.

Napier's reevaluation of previous notions of the framework for the evolution of the hand challenges existing thoughts on other narratives of the hand. For example, he contends,

> [w]hether the transition from tool-using to toolmaking and the subsequent improvement in toolmaking techniques can be explained purely in terms of cerebral expansion and the refinement of peripheral neuromuscular mechanisms, or whether a peripheral factor - the changing form of the hand - has played an equally important part in the evolution of the human species.[1214]

This highlights the importance of culture within the evolution of the hands and the brain, says Napier.[1215] Lemelin and Schmitt argue that in his 1962 paper in *Scientific American* and his posthumous, revised 1980 book edition, *Hands*[1216]*,* Napier acknowledges the paradox of primitiveness. Yet, the skill and specialisation of the hand make the term *primitive* more descriptive and explanatory by highlighting 'its specialised movements, its acute sensitivity, its precision, subtlety and expressiveness'[1217] due to its connection to the brain. Lemelin and Schmitt explain what Napier meant by primitive. By this, they think he means, quoting Napier's own words, 'make-up of this hand is the possession of five separate, and fairly equally developed digits'.[1218] This comparison of the human hand with five fairly equal fingers becomes expressly clearer in its importance when one looks at the chart of the variations in the structure and musculature of more evolved primate hands with various lengths and limited levels of opposability of the thumb, which Lemelin and Schmitt present in their chapter. They display a range of hands, from those of the Tree Shrew to humans, encompassing twenty variations of primate hand structure, as shown in Figure 59.

[1214] Napier, "The Evolution of the Hand," p57.
[1215] Napier, "The Evolution of the Hand," p57.
[1216] Napier and Tuttle, *Hands*.
[1217] Kivell et al., "On Primitiveness, Prehensility, and Opposability of the Primate Hand: The Contributions of Frederic Wood Jones and John Russell Napier," p7.
[1218] Kivell et al., "On Primitiveness, Prehensility, and Opposability of the Primate Hand: The Contributions of Frederic Wood Jones and John Russell Napier," p7.

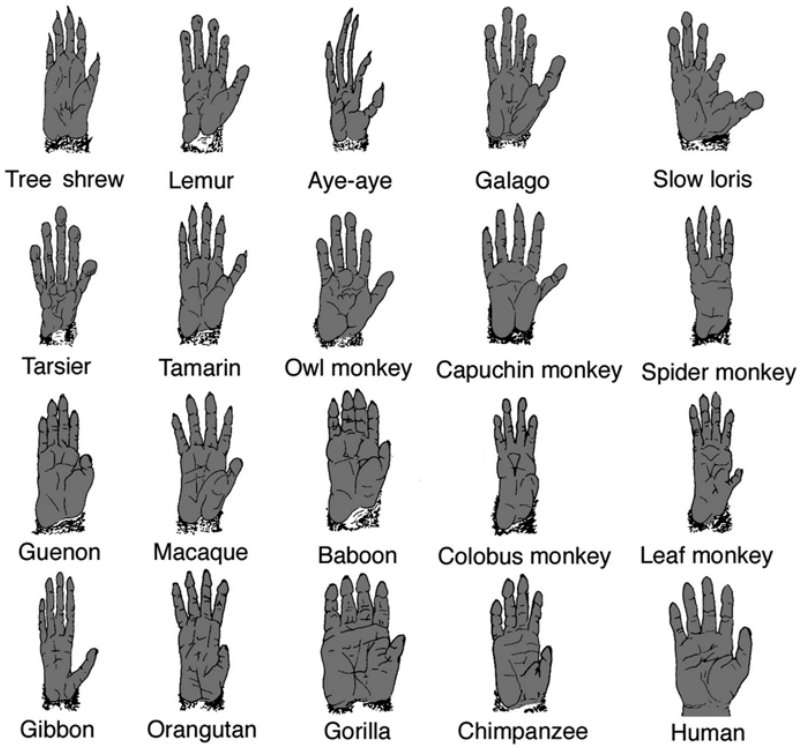


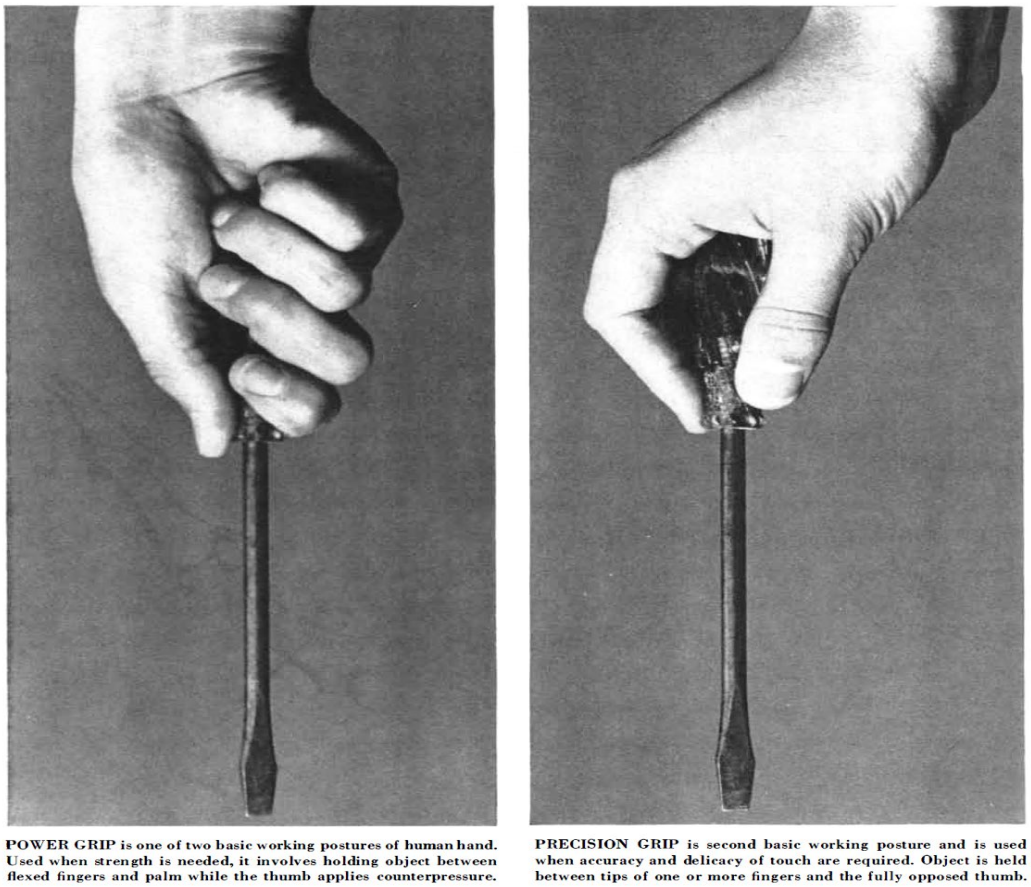
Figure 60 - Diversity in shape and proportions of the hand of primates and tree shrew (adapted from Schultz 1969). Note the reduction of the index finger in the slow loris or thumb of the spider monkey and colobus monkey compared to the elongation of digits 3 and 4 in the aye-aye (see Chap. 4 for more details). Hands not to scale. Taken from the Chapter by Lemelin and Schmitt 1219

The chart accounts for the variety and highly evolved, specialised version of the hand, noting its advanced derivative function for evolutionary adaptation by those species that exceed humanoid development. Some with exceedingly curled and lengthened third and fourth fingers, nearly twice the length of a human finger, such as the Aye-aye. Others, with nearly no thumb, instead have a stump, such as the Slow Loris and the spider monkey, which seemingly lack a thumb altogether.[1220] All these designs are configured by evolution for various types of environmental tree grip adaptation and mobilisation through various levels of the forest canopy. However, Lemelin, Schmitt, and Napier point out that these other animals developed even more specialised hand forms, which evolved further to form hooves, whale fins, and claws on bats. Each specialisation responds to its advancement and acclimation to its needs and the environment. Therefore, this comparison suggests that the primitiveness of the human hand indicates an arrest in development somewhere along the evolutionary tree, frozen in time in its original form, without further evolutionary advancement compared to other species. As suggested by Lemelin and Schmitt, these other species have evolved more in their hand specialisation. The arrested development in human hand evolution

[1219] Kivell et al., "On Primitiveness, Prehensility, and Opposability of the Primate Hand: The Contributions of Frederic Wood Jones and John Russell Napier," p8.
[1220] Kivell et al., "On Primitiveness, Prehensility, and Opposability of the Primate Hand: The Contributions of Frederic Wood Jones and John Russell Napier," p8.

reached a point where its dexterity matched its neuromuscular interface, aligning with its functionality and maintaining a state of topographic meta-stability with its physiology and anatomy.

The abilities of the hand that Napier speaks of —the five equally developed digits —have been studied intensively by a functional anatomist. It would be out of scope for me to review the body of work that describes the beauty and complexity of its functions. It is important to note, however, that the complex formation of its function is an expression of forces through its musculature. Its relationship to the brain gives the hand a unique ability to demonstrate two very important grips Napier recursively refers to in his 1965 paper: the two ultimate grips of the hand that give rise to civilisation. That being the 'power grip' and the 'precision grip'[1221]. These two grips illustrate the use of a screwdriver in two different modes of handling, as seen in Figure 2. These grips show the mastery of all tools.



POWER GRIP is one of two basic working postures of human hand. Used when strength is needed, it involves holding object between flexed fingers and palm while the thumb applies counterpressure.

PRECISION GRIP is second basic working posture and is used when accuracy and delicacy of touch are required. Object is held between tips of one or more fingers and the fully opposed thumb.

Figure 61 -The Power Grip and the Precision Grip taken from Napier's paper 'The Evolution of the Hand'[1222]

[1221] Napier, "The Evolution of the Hand," p58.
[1222] Napier, "The Evolution of the Hand," p58.

The ideas presented by Lemelin and Schmitt are to open up the debate about the evolution of the hand and its development through time and history. They propose a reconsideration and reflection amongst researchers on how 'special' the hand is.[1223]

Given this perspective on the biological evolution of the hand, we now turn to a new type of revolution in that evolution, that being the augmentation of an extra prosthetic finger to the hand in the variation of a third thumb, referred to in the literature as Supernumerary Robotic Finger (SRF) or Extra Robot Fingers (ERFs)[1224] or (XRAs)[1225] and its various proprietary names as developed by researchers. For this dissertation, we shall refer to the artifact at the centre of my research as the third-thumb or SRF.

[1223] Kivell et al., *The Evolution of the Primate Hand: Anatomical, Developmental, Functional, and Paleontological Evidence*, p11.
[1224] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook," p624.
[1225] Dominijanni et al., "The neural resource allocation problem when enhancing human bodies with extra robotic limbs," p850.

Appendix 3 - Four noteworthy reviews

To provide an overall understanding of SRFs, I will focus on four highly relevant reviews that collectively capture a substantial number of the papers found in our research that pertain to SRFs. I supplement these with the remaining papers, I believe, are important to the discussion on SRFs. The papers and projects these four reviews summarise together capture most of the current research on SRFs in the literature review. These are the four comprehensive reviews that work together as a whole. Together with a database search carried out using relevant search terms, these papers provide a comprehensive overview of the current state of the field of SRFs.

The SRFs are sometimes interchangeably referred to as an artifact, a third-thumb paradigm, or a third-thumb, even though some projects discuss the augmentation of more than one finger/thumb. The reason for referring to them as paradigms or artifacts is that they are not just objects of engineering but encompass broader instruments of cultural and social significance. They have technical particularities; their conceptual qualities make them artifacts of interest in the discourse later in the chapter, when discussing the issues of psychoanalysis related to subjectivity.

Most of the papers in this review are highly technical and based on the field of interest in mechatronics, engineering, and robotics. There is no value in exploring the highly technical character of various systems' technicities other than to uncover the meaning of the innovations in terms of the technologies, their achievements, and the challenges they pose in making a truly wearable technology that may one day become ubiquitous and socially and culturally acceptable. Together, these projects offer a glimpse of the future for wearable SRFs or third-thumbs or fingers.

The four reviews of interest were published between 2021 and 2023 and capture over two decades of research in SRL development. I shall extract the relevant information specific to SRFs from the various sections of these reviews that are relevant to SRFs only.

The most recent review, by Liao et al. (2023), focuses on device design and is published in the journal Industrial Robotics, referencing two of our other reviews. It is titled 'A Human Augmentation Device Design Review: Supernumerary Robotics Limbs'[1226].The next most recent paper was published in August 2021, is one by Yang et al. published in IEEE Xplore, titled 'Supernumerary Robotic Limbs: A review and Future Outlook'[1227], which does not reference any other reviews. The other paper that was published nearly simultaneously was a review by Prattichizzio et al., 'Human

[1226] Liao et al., "A human augmentation device design review: supernumerary robotic limbs," p256.
[1227] Yang et al., "Supernumerary Robotic Limbs: A Review and Future Outlook."

augmentation by wearable supernumerary robotic limbs: Review and perspectives'[1228] was published in Progress in Biomedical Engineering (Prattichizzio et al. a very well-known researcher in the field) which referenced both Yang et al. and Tong et al. in September 2021. Several months before these two papers were published, Tong et al. reviewed the first of these four reviews in May 2021 for her PhD, and it's a well-written and structured piece in the IEEE/CAA Journal of Automatica Sinica titled 'Review of Research and Development of Supernumerary Robotics Limbs'[1229]. There are several other reviews preceding and following this one. Still, these are the most significant reviews to date that specifically examine the most important SFR projects, to which I will refer in the coming chapter(s). It is for the comprehensiveness and breadth of perspectives in their writing that these four papers were chosen. They shall help structure this review to blend the missing SRF research, which I will add to complete my research on SRFs with other notable works.

[1228] Prattichizzo et al., "Human augmentation by wearable supernumerary robotic limbs: Review and perspectives."
[1229] Tong and Liu, "Review of Research and Development of Supernumerary Robotic Limbs."