Wellbeing, Belonging and the Emotional Dynamics of Social Exclusion in Primary School

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Author's Declaration

This is to certify that, to the best of my knowledge:

i. *The content of this thesis is my original work.*

ii. *This thesis has not been submitted for any degree or other purpose.*

iii. *The intellectual content of this thesis is the result of my own work.*

iv. *All assistance received in preparing this thesis and the sources have been acknowledged.*

v. *This thesis complies with the protocols for conducting research established by the Human Research Ethics Committee (HREC) at the University of Sydney.*

vi. *No content produced by generative AI tools has been used in the preparation of this thesis.*

Signature:

Name: Li Li

Date: 30/03/2025

Contribution of the Candidate

The research presented in this thesis was conducted by the candidate at the Sydney School of Education and Social Work, Faculty of Arts and Social Science, at The University of Sydney, under the supervision and guidance of A/Prof Minkang Kim. Permission to conduct the empirical study was granted by the Human Research Ethics Community (HREC) (Project No.2020/487) at The University of Sydney (see Appendix A-1).

The candidate is responsible for conducting and coordinating research under the supervision of A/Prof Minkang Kim. The candidate took primary responsibility for conceptualising and designing the research and for collecting and analysing all relevant data sets. The candidate designed the data collection procedures and collected the data from the EEG experiment.

The candidate is the primary author responsible for formulating, drafting, revising, and submitting all manuscripts for this thesis, with support and guidance from A/Prof Minkang Kim, the project's Primary Supervisor. The candidate was responsible for writing, revising, and submitting the thesis.

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People often wonder why I'm pursuing a PhD at this stage of my life, and many assume it's for a different career path or material gains. But for me, the answer is quite simple: I just enjoy learning new things and sharpening my mind! Emotions have always fascinated me, probably because they have been a source of personal struggle since my early childhood. I often think of that little girl crying for hours at home if something upset her, feeling left out at school and disliked by others. Her disobedience and unhappiness followed me into adulthood. This emotional pain continues to affect my ability to regulate my emotions, significantly impacting both my personal life and career growth as I navigate adulthood. I have grappled with my feelings throughout my life, so I am eager to learn more about them, hoping that a deeper understanding of this subject will help me navigate the pain and challenges I face. To me, completing a PhD is not just an academic pursuit; it is a remarkable journey of personal growth.

Throughout this journey, I have faced numerous challenges; however, the thought of not completing my PhD has never crossed my mind. This determination likely stems from my lifelong love of learning, which has been nurtured since childhood. I am profoundly grateful to that little girl from a small town in Sichuan, China, who was determined to pursue her education, even when she never imagined attaining a PhD. As this journey draws to a close, I feel a deep sense of gratitude, recognising that I couldn't have reached this point without the support of many people. To them, I extend my heartfelt thanks.

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Glossary of Abbreviations

ACBPS	Australian Covert Bullying Prevalence Study
AGDE	Australian Government Department of Education
AIHW	Australian Institute of Health and Welfare
DST	Dynamic Systems (Complexity) Theory
EEG	Electroencephalogram
EPIC	Embodied Predictive Interoception Coding
ERP	Event-Related Potential
FRN	Feedback-Related Negativity
LPP	Late Positive Potential
MEM	Mixed-Effects Model
NTS	Need Threat Scale
OECD	Organisation for Economic Co-operation and Development
PDHPE	Personal Development, Health, and Physical Education
PIRLS	Progress in International Reading Literacy Study
PISA	Programme for International Student Assessment
SAS	Social Acceptance Scale
SBS	School Belongingness Scale
SEL	Social and Emotional Learning
SES	Social Exclusion Scale
SJP	Social Judgment Paradigm
SPN	Stimulus Preceding Negativity
TNGS	Theory of Neuronal Group Selection

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Data Availability Statement

The datasets presented in this thesis are not publicly available because ethical approval to place the data in a public repository was not obtained from the students who participated in this study (Project No. 2020/487). However, the data may be made available upon request to the author, following a review by the Human Research Ethics Committee (HREC). Requesters should submit a data analysis plan before requesting access to the data. Requests for data access should be directed to either Li Li or A/Prof Minkang Kim.

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Conference Presentations Related to this Thesis

The conceptual basis of the study was presented as a paper during the symposium titled “Under the microscope: The dynamics of moral and empathic development and learning” at the 46th Annual Conference of the Association of Moral Education (Online) on 31 October 2020.

Part of the results from this PhD project, titled “Children’s Wellbeing and Learning: Emotional Dynamics of Social Exclusion in Primary School,” were presented at the Association for Moral Education Annual Conference in New York, United States, on 25 October 2024.

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Abstract

It is widely recognised that positive peer relationships enhance children's social development and are instrumental in promoting their health, adjustment, and academic success. Conversely, negative peer relationships can significantly impede a child's social development, academic learning, and overall social and neurobiological well-being. One prevalent and hostile form of negative peer relationships is the feeling of being socially excluded or ostracised by peers. According to the Organisation for Economic Co-operation and Development (OECD) report published in 2019, an average of 9% of students across OECD member countries reported experiences of deliberate exclusion. In other words, close to one in every 10 students, across OECD member countries are subjected to this kind of social harm.

In contrast to many previous studies that have focused on investigating the perpetrators of social exclusion, for example, their motivations, this thesis focuses on the *emotionally felt experiences of victims*, with special reference to Australian primary schools and beyond. This study posits that social exclusion is not only a social harm; at the level of individual persons, it constitutes an existential harm that inflicts neurobiological damage on its victims. Some previous studies have provided generalised accounts of the pain endured by victims of social exclusion, as evidenced by their self-reporting. However, by adopting a multi-modal approach that gathers and analyses self-reported survey data alongside and together with electroencephalogram (EEG) data, this thesis pushes past the generalised notion of pain evoked by social exclusion, to provide a more nuanced account of the emotionally felt experiences of victims, especially how these experiences correlate with children's feelings of *emotional well-being and sense of belonging* within the school environment.

A novel conceptual framework was developed to investigate the existential experience of social exclusion, drawing upon contemporary neuroscientific insights concerning the embodied, socially, and culturally embedded predictive Bayesian brain. This framework, which is consistent with the neurobiology of the brain as a dynamic, complex system, incorporates the notion of 'here-and-now' 'feedback loops' that operate at the intersection of the predictive, embodied brain and immediate contexts. By incorporating EEG and Event-Related Potential (ERP) technology into the research design, this study was able to investigate both the conscious but also, and significantly, the subconscious impacts of social exclusion in schools. It is believed that this begins to bridge a significant gap in the existing literature, which currently offers little insight into the conscious and virtually nothing regarding the subconscious impacts of social exclusion on students' well-being and sense of belonging.

The empirical data garnered by this study not only corroborates much previous research showing that when being introduced to a group of similar-aged children, children exhibit an emotional desire to be accepted and to feel they belong within the new community. It provides significant, though provisional, evidence that real-time neural processes significantly correlate with a child's self-reported responses regarding immediate distress from social exclusion, and with their sense of school belonging. Moreover, a strong sense of belonging to one's own school acts as a protective factor, enhancing emotion regulation and reducing distress when threatened by an unknown peer's rejection. In providing a more nuanced and comprehensive account of the experience of social exclusion that is hitherto unavailable in the literature, the findings of this study will go some way toward a better-informed platform for developing effective social exclusion intervention practices in Australian primary schools and beyond.

Chapter 1 Introduction and Overview

1.1 Peer relationships and the harms of social exclusion at school

Many decades of empirical research have demonstrated that peer relationships significantly impact children's learning and development, from a very young age, in both positive and negative ways (Hay, 2005). Positive peer relationships substantially enhance children's social development and are instrumental in promoting their health, adjustment, and academic success (Ladd, 2005). Indeed, a "substantial body of evidence indicates that healthy peer relations are an essential resource for children's development" (Kochenderfer-Ladd & Ladd, 2019, p.39), and positive peer relationships facilitate "healthier developmental trajectories" (p.39). They also enhance children's emotional and social well-being, thereby improving their ability to learn because "learning and development are intimately related to student well-being in school" (Kim & Sankey, 2022, p.289). This is evident not only socially but also neurobiologically because, as this thesis demonstrates, the neural correlates of well-being occur in the brain. Conversely, destructive peer relationships significantly impede a child's social development, academic learning, and overall social and neurobiological well-being, and this detrimental effect commences during the early years of child development (Hay, 2005).

Nevertheless, conflicts and disagreements among peers are inevitable during childhood. These experiences can play a pivotal role in shaping children's self-perception and provide opportunities to develop critical *social* skills, such as perspective-taking (Ladd, 2005). Peer relationships, whether positive or negative, are formed in various social contexts. However, given the significant amount of time children invest in early childhood educational settings and schools, adverse peer interactions encountered in these environments can have a considerable impact on a child's cognitive, psychological, physical, and social well-being (Organisation for

Economic Co-operation and Development [OECD], 2019). Ladd (1999) emphasises that “poor peer relations during childhood were consistently implicated in the aetiology of later deviance” (p. 334). Hay (2005) highlights extensive research supporting claims about the effects of negative peer relationships on cognitive and social development. This research includes experimental, observational, sociometric and ethological studies, much of which demonstrates that negative peer relations in early years “may have adverse effects on the transition to school, with subsequent consequences for academic success” (Hay, 2005, p.1). Considering the substantial research indicating the profound influence of detrimental peer relationships on cognitive and social development, this thesis specifically addresses one prevalent and hostile form of negative peer relationships: *social exclusion* (in the sense of social rejection) as it occurs within primary schools, particularly in Australia, but also globally.

It should be noted that, in the literature, the term ‘social exclusion’ is sometimes used to describe schools excluding or expelling students. However, this thesis does not focus on that aspect, as it exclusively addresses peer rejection rather than institutional rejection. Social exclusion, particularly in the form of peer rejection, is broadly defined as “the experience of being kept apart from others physically or emotionally” (Wesselmann et al., 2016, p. 5). In social psychology, another term frequently used in conjunction with peer exclusion and peer rejection is ‘ostracism’ (Williams & Nida, 2016). Williams (2001) characterises ostracism as ‘the power of silence’, a tactic that may be wielded against both individuals and groups. Concerning individuals, he posits that it inevitably invokes pain as an initial response, irrespective of personality traits and varying social and situational contexts. This assertion aligns with the application of social exclusion in this thesis; however, the primary focus herein is strictly on the subjective experiences of individuals, rather than those of groups. The experiences of social exclusion among children, which may begin in early childhood settings but become particularly pronounced within the school environment, constitute a notably severe form of detrimental peer relationships that “thwart fundamental human needs and threaten… mental health and well-being” (Arsian, 2018, p. 897) and “can occur for a myriad of reasons” (Mulvey et al., 2018, p. 71).

The existing literature regarding social exclusion within educational environments has predominantly concentrated on the exclusionary behaviours exhibited by peers (Ladd & Kochenderfer-Ladd, 2016, provide a comprehensive review), whereas the main concern of this thesis is the *excluded student* and the “subjective perception of being ignored and rejected by others” (Arslan, 2018, p. 964). As just noted, there are very many reasons why some children at school may be excluded by their peers. Ladd (1999) speculated that such exclusionary behaviours among peers might be “attributable not only to deficits in behavioural skills but also to the cognitions that might underlie and maintain such deficits, such as misplaced goals or strategies, biased interpretations of peers’ motives, and debilitating self-perceptions” (p. 336). Nevertheless, this endeavour to elucidate psychological explanations based on the notion of behavioural or cognitive *deficits* seems to assume that social exclusion is always a product of insidious intent. This perspective overlooks the possibility that individuals who exclude others from their peer group may be acting to achieve what *they* perceive to be desirable ends, for example, keeping the group within certain social or behavioural bounds or punishing a peer for acting unkindly towards others. Whatever justification the perpetrators of social exclusion might provide for their behaviours, the intended emotional impact on the recipient or victim of social exclusion is likely to be emotionally painful (Williams, 2001; Williams & Nida, 2016). Indeed, neuroimaging studies have demonstrated that the pain of exclusion involves areas of the brain similar to those involved in physical pain (Eisenberger & Lieberman, 2004).

The main purpose of this thesis is to open the phenomena of social exclusion in schools to probing enquiry, with a particular focus on the *emotionally felt experiences of victims*. This endeavour is informed by Williams's (2001) assertion that individuals commonly respond to social exclusion and ostracism with feelings of 'pain', irrespective of their personality and the differing social and situational contexts. However, by garnering and analysing self-reported survey data triangulated with electroencephalogram (EEG) data, this thesis will go beyond Williams' generalised notion of 'pain', to provide a more nuanced account of the emotionally felt experiences of victims, especially in terms of their feelings of *emotional wellbeing and sense of belonging* at school. This 'multi-modal approach' will probe both the conscious and subconscious impacts of social exclusion in schools, which will address a quite significant gap in the literature that currently offers little insight into the conscious experiences of being a victim of social exclusion and virtually nothing about the subconscious impacts of social exclusion on students' well-being and sense of belonging. Hopefully, the results yielded by this approach will begin to point the way to how social exclusion might start to be eliminated in Australian primary schools, and elsewhere.

1.1.1 Student learning, development and feelings of well-being and belonging at school

The *Australian Student Well-Being Framework* envisions schools as learning communities that nurture students' well-being, safety, and positive relationships, thereby enabling them to realise their full potential (Education Services Australia, 2018a). The Australian curriculum for primary students also acknowledges the importance of students' well-being. For instance, Personal Development, Health, and Physical Education (PDHPE) constitutes one of the Key Learning Areas within the K-6 curriculum in New South Wales, Australia. This curriculum aims to empower students by providing them with the essential knowledge, understanding, skills, values, and attitudes necessary to promote well-being and facilitate a safe, active, and healthy life (NSW Education Standards Authority, 2025).

Numerous factors can dynamically and significantly impact students' well-being and learning, with a notably prominent indicator being their sense of belonging within the educational environment. A recent review by Education Services Australia (2018b) of the *National Safe Schools Framework* highlights that *connectedness* acts as a protective factor for children and adolescents, indicating when students feel a sense of belonging, they are more likely to adopt healthy behaviours, attain higher academic achievements, and significantly reduce their engagement in risk-taking activities. Findings from Australia's Progress in International Reading Literacy Study (PIRLS) 2021 revealed that an enhanced sense of belonging at school correlated with significantly improved reading performance (Hillman et al., 2023). Internationally, OECD's Programme for International Student Assessment (PISA) (2019) provides evidence that students across OECD countries who reported an increased sense of belonging achieved higher scores in reading assessments; they also demonstrated elevated levels of cooperation among peers and a greater propensity towards pursuing higher education. Moreover, a sense of belonging at school has been acknowledged as a crucial predictor of both externalising and internalising issues, and overall life satisfaction among youth aged 10 to 15 years (Arslan et al., 2020).

Although, as evidenced above, much educational literature recognises that student well-being and sense of belonging within the school environment are critical in facilitating children's learning and academic and personal growth, student learning, development, well-being, and belonging are often presented as separate and distinct, in the overall learning and developmental process. This contrasts with the position articulated in the present thesis, which asserts that students' learning, ongoing development, well-being, and sense of belonging in school are holistically and dynamically interwoven. Mary Helen Immordino-Yang and Antonio Damasio (2007) suggest part of the reason for viewing them separately is that many educators and education policymakers "often fail to consider that the high-level cognitive skills taught in schools, including reasoning, decision-making, and processes related to language, reading, and mathematics, do not function as rational, disembodied systems, somehow influenced by but detached from emotion and the body" (p.3). Instead, they say, "these crowning evolutionary achievements are grounded in a long history of emotional functions, themselves deeply grounded in humble homeostatic beginnings" (p.3).

As elaborated later in this thesis, the evolution of the human brain was such that it allowed humans to regulate physiological functions, enhance survival prospects, and promote human flourishing (Sterling, 2012). Given that this necessitates monitoring and modifying the states of both the body and mind in increasingly complex ways, it becomes evident that emotions, manifested in both the body and mind, are intricately intertwined with cognition (Barrett, 2018). This connection should not be deemed surprising, as complex brains could not have evolved independently of the organism they regulate (Damasio, 2012). As human brains became more sophisticated and human societies evolved, the challenge of surviving and thriving transitioned from merely managing oneself within the environment to successfully navigating social interactions and relationships within increasingly complex contexts (Immordino-Yang & Damasio, 2007). In short, humans are inherently emotional and social beings with an intrinsic need for connection and belonging (North & Fiske, 2013; William, 2007; Kim & Sankey, 2022). In contrast, as will be elaborated upon in greater detail in Chapter 2, social exclusion infringes upon this essential human need. In the subsequent sections, we will present a concise discussion of the detrimental effects of social exclusion from various theoretical standpoints.

1.1.2 Defining social exclusion as overt and covert bullying harm

Social exclusion in educational contexts is increasingly recognised as a form of relational aggression or covert bullying, where individuals suffer harm through the manipulation of their social relationships and status (Cross et al., 2009). OECD (2019) and the Australian Institute of Health and Welfare (AIHW) (2020) categorise bullying into three distinct types: physical, verbal, and social or relational. According to these definitions, social exclusion is categorised as relational bullying (OECD, 2019) or social bullying (AIHW, 2020), which can be either overt or covert; the latter often makes it challenging for teachers and other adults to recognise (Cross et al., 2009). OECD's PISA report indicated that verbal and relational bullying was more prevalent than overt bullying (e.g., physical bullying) (2019). On average, across OECD countries, approximately 7% of 15-year-old students reported experiencing physical harm at least a few times a month or having personal belongings taken or destroyed by other students. Meanwhile, 14% of students reported being teased at least a few times a month, 10% said they were the subjects of nasty rumours at school, and 9% reported being deliberately excluded (e.g., left out of activities) (OECD, 2019).

In Australia, the Australian Covert Bullying Prevalence Study (ACBPS) published in 2009 revealed that 27% of Australian students in Year 4 to Year 9 experienced frequent bullying (Cross et al., 2009). The more recent data from Australia's results from PIRLS 2021 showed that approximately 35% of Australian Year 4 students reported experiencing frequent bullying (Hillman et al., 2023). These data show an increase in the prevalence of bullying among Australian students. It is worth noting that a significant majority of students (61%) who reported being bullied in any form also encountered covert bullying, either independently or in conjunction with overt bullying (Cross et al., 2009), and over half (53%) of students who admitted to bullying others had engaged in covert bullying, either solely or in combination with overt bullying (Cross et al., 2009). Moreover, *one in six* students (16%) disclosed that they had been bullied covertly every few weeks or more often during the term (Cross et al., 2009). More participants recognised social exclusion (such as being deliberately ignored, denied participation, or intentionally left out) as a form of covert bullying and distinguished it from other types of bullying, such as fear of physical harm (Cross et al., 2009).

With older Australian students from grades seven to eleven, an Australian study (Thomas et al., 2016) indicated that adolescents reported four prominent forms of bullying with high prevalence: verbal teasing or name-calling (30.6%), spreading of rumours (17.9%), social exclusion (14.3%), and physical threats or harm (10.7%). Rumour spreading and social exclusion fall under the category of relational or social bullying. Notably, a total of 32.2% of Australian students in grades seven through eleven reported having experienced relational or social bullying (Thomas et al., 2016). Currently, there is no recent information regarding covert or relational bullying among younger Australian students, but given that overall statistics related to bullying have risen from 27% in 2009 (Cross et al., 2009) to 35% in 2023 (Hillman et al., 2023), it is likely that incidents of covert bullying have similarly increased, if not to a greater extent in this cohort.

The recognition of social exclusion as a form of relational and social bullying, as identified by the OECD (2019) and AIHW (2020), is essential for raising the awareness and seriousness of this specific form of social harm experienced in educational settings. However, many definitions of social exclusion and the statistics reported by the OECD, PIRLS and ACBPS often neglect the emotional and existential impact of social exclusion inflicted upon the victims and what this might be doing at the neurobiological level. This study focuses particularly on the emotional impact of social exclusion among children aged 8 to 10, especially as these effects occur neurobiologically, as manifested in EEG measurements and what are known as Event-Related Potentials (ERPs), to be elaborated later in this chapter.

1.1.3 Social exclusion as a form of existential harm

From the perspective of this present study, social exclusion is also a form of existential harm that can threaten a child's healthy developmental sense of *belonging* in the world, at home and in the community, including the school community, along with a sense of *being* a person of worth, in the process of *becoming*, developmentally. The *Early Years Learning Framework for Australia* is founded on "a view of children's lives as characterised by *belonging, being, and becoming*" (Australian Government Department of Education [AGDE], 2022, p.6) and adopted these three keywords as the title of the *Framework* document. The document notes that experiencing a sense of belonging- "knowing where and with whom you belong"- is not only "integral to human existence" but also "central to being and becoming in that it shapes who children are and who they can become" (AGDE, 2022, p. 6). The corollary of this important existential claim is that the denial of positive peer relationships, as exemplified by being socially excluded, either inadvertently or deliberately, undermines a child's feelings of belonging and hence their existential sense of being and becoming - who they are and who they can become - and therefore constitutes an existential harm.

To further develop this important existential perspective, the *Early Years Learning Framework* posits that "Belonging, being, and becoming are integral parts of identity. A healthy identity is the cornerstone to children's learning, development, and wellbeing" (AGDE, 2022, p.30). As children grow, their social networks continue to expand, and "over time, the variety and complexity of ways in which children connect and participate with others increases" (AGDE, 2022, p.38). When children enter early childhood settings and schools, peers play an increasingly significant role in their lives. Peer relationships become more influential in shaping their identity as “relationships are the foundations for the construction of identity – ‘Who I am’, ‘How I belong’, and ‘What is my influence?’” (AGDE, 2022, p.30). “Having a positive sense of identity and experiencing respectful, responsive relationships strengthens children’s interests, knowledge, and skills in being and becoming active contributors to their world” (AGDE, 2022, p.38). Children gain confidence to explore and learn only when they feel safe, secure, and supported (AGDE, 2022). A sense of belonging fosters wellbeing, and “a strong sense of wellbeing provides all children with confidence and optimism which maximise their learning potential” (AGDE, 2022, p.44). In turn, “a strong sense of wellbeing strengthens a sense of belonging and encourages children to trust others and feel confident in being” (AGDE, 2022, p.44).

The existential importance of belonging in shaping a child’s sense of being and becoming is, however, not restricted to the early years; it equally applies to child and adolescent development, learning, and well-being throughout school years and into adulthood. This is mirrored in contemporary educational research, which “is increasingly tying academic achievement to the contextual dynamics of personal meaning-making and social-emotional feelings” (Immordino-Yang & Gotlieb, 2017, p.345).

1.1.4 Social exclusion as a form of neurobiological harm

Contemporary neuroscience indicates that social exclusion can inflict neurobiological damage on its victims. Specifically, social exclusion may lead to social pain for these individuals (Borsook & MacDonald, 2013; Eisenberger, 2013). “Social pain is the emotionally aversive, pain-like experience that can attend socially excluding events (and the memory of such events)”

(Borsook & MacDonald, 2013, p. 173). An increasing body of evidence indicates that social pain activates some of the identical neural circuitry and biological systems associated with physical pain (Borsook & MacDonald, 2013; Eisenberger, 2013). For instance, a neuroimaging study determined that “the experience and regulation of social and physical pain share a common neuroanatomical basis” (Eisenberger et al., 2003, p. 291). Activity in the dorsal anterior cingulate cortex (ACC), previously associated with the experience of pain distress, is linked to heightened distress subsequent to social exclusion, and activity in the right ventrolateral prefrontal cortex (RVPFC), recognised for its role in regulating pain distress, correlated with a decrease in distress following social exclusion (Eisenberger et al., 2003). As highly social beings, we find social exclusion deeply distressing. On the other hand, however, though social exclusion or broken relationships can be painful in the short-term, they may also serve an adaptive role long-term, helping to preserve close social connections (Eisenberger, 2013).

In conclusion, social exclusion is regarded as both overt and covert bullying within educational settings. A neurobiological understanding of social exclusion as a form of neurobiological impairment offers significant insights into this phenomenon. Furthermore, the current study contends that social exclusion, as a manifestation of existential harm, introduces a philosophical dimension to this occurrence.

1.2 The science of emotion and development and education

Traditionally, in the West, especially throughout the Enlightenment, emotion and cognition were perceived as two distinct domains that function independently of one another. Moreover, emotion and rational thought or cognition were conceived as incompatible; to be rational and objective, one had to put aside all emotion. This entrenched view was challenged in the last decade of the twentieth century by Antonio Damasio (1994) and others. Research involving neurological patients with damage to the ventromedial prefrontal cortex (VMPFC) yielded evidence that emotion is not only necessary to temper cognition but also that the absence of emotion (not having a 'feel' for the situation at hand) can result in highly irrational actions that may threaten even survival (Damasio, 1994). In this century, it has become increasingly clear that the brain functions as an integrated organ, with all its neurological functions operating in a coordinated manner (Barrett, 2017; Dennis, 2010; Immordino-Yang & Damasio, 2007; Immordino-Yang & Gotlieb, 2017; Mosier, 2013). Thus, contrary to the Enlightenment claim that emotion and cognition are two distinct and separate mental domains, they are, instead, inherently interconnected within each individual brain.

Moreover, lesion (brain damage) studies have shown that individuals with neurological impairments resulting from damage to the VMPFC often exhibit a number of deficiencies, including insensitivity to the emotions of others, an inability to learn from past errors, breaches of social norms and ethical standards; an absence of embarrassment or the capacity to offer empathetic support; an inadequate performance in occupational roles, despite possessing the necessary skills; and a tendency to make decisions that are often detrimental to themselves and their families (Immordino-Yang & Damasio, 2016). These individuals do not experience a decline in knowledge or a reduction in their thinking abilities in the conventional sense; they do, however, exhibit a deficiency in a cerebral region critical for processing social emotions, resulting in a failure to analyse situations for their emotional implications and to appropriately tag memories of these experiences (Damasio, 1994). Their emotional responses become dissociated from rational cognition, leading to compromised reasoning, decision-making, and learning capabilities (Immordino-Yang & Damasio, 2016).

Additionally, Immordino-Yang and Damasio (2016) emphasise that individuals who have experienced comparable prefrontal damage during early childhood, as opposed to adulthood, exhibit cognitive normalcy in the conventional IQ sense and demonstrate the capacity for logical reasoning and factual knowledge in educational settings. However, these individuals display insensitivity to notions of punishment and reward, and they do not pursue approval or social acceptance as is typically observed in their peers. Upon reaching adulthood, they often struggle to manage their lives effectively, tend to waste time, deplete resources, and engage in hazardous, antisocial, and aggressive behaviours. In comparison to adult-onset patients, childhood-onset patients seem to have never acquired the rules that govern social and moral behaviour. The childhood-onset patients may be suffering from the loss of their 'emotional rudder', resulting in a diminished ability to manipulate situations and mark them as positive or negative from an affective perspective. They struggle to learn social behaviours, lose corresponding decision-making abilities, fail to respond to educators' and others' attempts to teach them appropriate behaviour, and cannot apply non-social knowledge learned in school to guide their everyday lives, even in non-social contexts (Immordino-Yang & Damasio, 2016).

Throughout the course of human evolution, the human cortex and subcortex have experienced notable transformations (Miller & Clark, 2018). Growing evidence indicates that these cortical and subcortical regions have evolved in a highly synchronised fashion, resulting in intricate interdependencies between essential emotional circuits and advanced cognitive functions (Miller & Clark, 2018). Additionally, subcortical circuits are closely linked to internal bodily processes, encompassing vascular, visceral, endocrine, and autonomic systems (Miller & Clark, 2018). This points to the notion that bodily information possesses greater importance than previously assumed within the corticocentric paradigm of the brain (Miller & Clark, 2018). Such a relationship encourages a profoundly 'embodied' perspective, as there are interrelated connections characterised by continuous reciprocal causation among the body, subcortex, and cortex (Miller & Clark, 2018).

Furthermore, from an evolutionary standpoint, our nervous systems came to the stage later to serve the rest of the organisms – bodies, not the other way around (Damasio, 2018). Our brain originally evolved "to manage our physiology, to optimise our survival, and to allow us to flourish" (Immordino-Yang & Damasio, 2007, p.4). Instead of merely reacting to stimuli, the brain continuously monitors and predicts prior to any stimulus, thereby fulfilling its allostatic needs with minimal expenditure (Barrett & Simmons, 2015; Clark, 2013; Sterling, 2012). As our environment becomes increasingly complex, the demands for survival and flourishing compel both the brains and the minds they support to deal not only with one's own self but also navigate effectively within this remarkably intricate social and cultural landscape (Immordino-Yang & Damasio, 2007). As this thesis emphasises, children's emotions are a fundamental neurobiological and social component of their school experience, not only in terms of the achievement learning outcomes, though that is important, but also surviving and flourishing in school, which may include surviving the experience of being socially excluded.

Given the paradigm shift in our understanding that emotion and thought are interwoven in the brain, and the subsequent and extensive body of research into the science of emotion, which will be elaborated in Chapter 2, it is evident that emotions are intricately connected to and can significantly impact the cognitive dimensions that are predominantly engaged in education. These include learning, memory, attention, motivation, decision-making, creativity, and social functioning (Mosier, 2013). For example, the realisation that children's thinking is laced with emotion, and it is "neurobiologically impossible to build memories, engage complex thoughts, or make meaningful decisions without emotion" (Immordino-Yang 2016, p.18). Moreover, memories of events are not stored in the brain as complete wholes; rather, they are perpetually *reconstructed* from various regions of the brain, and their reconstruction is often deeply influenced by emotion, as are children's values and the choices they make (Sankey, 2006).

Over the past 30 years or so, it has become imperative to reassess and amend numerous existing educational policies and classroom practices (Kim & Sankey, 2022). Learning domains that are often marginalised, such as PDHPE and the Arts, deserve a more significant role and increased curriculum time. Currently, according to the guidelines set forth by the NSW Education Standards Authority (2023), primary schools in New South Wales are recommended to allocate approximately 6 -10% of the teaching week, which corresponds to approximately 1.5 to 2.5 hours, to PDHPE or the Arts. In comparison, considerably larger portions are designated for English and Mathematics, with recommendations of 25-35% and 20%, respectively. The advised allocation of 1.5 to 2.5 hours for PDHPE or the Arts is evidently insufficient, given their critical importance in promoting students' physical, emotional, and social well-being, as well as the intrinsic relationship between learning and student well-being. Alarmingly, these educational areas are frequently the first to be eliminated when the school week becomes more demanding, as educators prioritise covering content in English and Mathematics.

The well-being of children, encompassing their social and emotional development, constitutes a fundamental aspect of early childhood education. As highlighted in the *Early Years Learning Framework*, three out of five learning outcomes for Australian children under 5 years old are closely related to their social and emotional development - children have a strong sense of identity; children are connected with and contributed to their world; children have a strong sense of well-being (AGDE, 2022). These outcomes emphasise the significance of children's relationships with others, as "relationships are the foundations for the construction of identity" (AGDE, 2022, p.30). Only when children experience a sense of belonging in their educational settings, "when they feel safe, secure, and supported they grow in confidence to explore and learn" (AGDE, 2022, p.30). More specifically, Outcome 3 focuses on children's social, emotional, and mental well-being (AGDE, 2022).

These early learning focuses shift dramatically as children commence their formal education within Australian schools. The learning outcomes within these academic environments primarily concentrate on academic success. Although many educators acknowledge the substantial impact that students' social and emotional well-being has on their learning and behaviour in school, they face constraints in time and resources to adequately address these aspects, as their schedules are predominantly occupied with instructing so-called 'cognitive content', particularly subjects that can be quantitatively assessed through conventional assessments or standardised testing. In addition, "the relationship between learning, emotion and body state runs much deeper than many educators realise and is interwoven with the notion of learning itself" (Immordino-Yang & Damasio, 2007, p.3). Due to constrained resources and a lack of understanding regarding the profound influence of emotion on students' learning and performance, educational institutions and educators strive to assist students in attaining various academic outcomes dictated by the curriculum; however, instruction regarding students' social and emotional development is, if not entirely disregarded, at the very least relegated to a secondary concern, with relevant content being taught only in instances when *time permits.* From the point of view of this thesis, bringing educational policies and practices in schools into line with the extensive research on the interplay of emotion and thought within the brain, which implies bringing children's social and emotional development to the centre of the curriculum, as it is in early childhood education, would help pave the way to addressing social issues such as the scourge of social exclusion in schools.

1.3 The embodiment of emotion within the Bayesian predictive brain

In the previous Section (1.2), it was said, contrary to much contemporary belief, that the brain does not merely react to incoming perceptual stimuli, rather it continuously and proactively predicts what stimuli it should be receiving and acts only when there is a discrepancy between what is expected and what is received, thereby fulfilling its allostatic needs with minimal expenditure. Basically, allostasis is process by which the brain maintains balance and stability while constantly undergoing change. Over the past decade, the notion of the predictive brain has gained popularity as an alternative to traditional notions of information processing that between the higher 'cognitive brain' and the subordinate 'emotional brain' (Miller & Clark, 2018). This alternative is often called 'Bayesian predictive processing', after the English seventeenth century philosopher and statistician Thomas Bayes, who developed a theorem of probabilistic inferences. In a very recent version developed by British researcher Karl Friston, the Bayesian predictive process is referred to as 'active inference', or 'probabilistic inference' and incorporates what Friston and his fellow researchers call the "free energy principle in mind, brain, and behaviour" (Parr, et al., 2022). It is crucial to appreciate that the brain's predictions are informed by past experience and prior expectations, which are optimised across diverse somatic and evolutionary timescales, thus determining what holds value (Friston, 2010).

Three concepts are essential to understanding the Bayesian brain, namely 'connectivity', 'value' and 'core affect'. Regarding the brains' extensive, functional 'connectivity', unlike many other functionally specialised cells in the human body, such as liver cells or blood cells that lack delicate connectivity, the brain's neurons and neuronal pathways are massively connected and interconnected. This enables the brain to make "inferences about the causes of its sensations" by modelling "the causal relationships (connections) among (hidden) states of the world that cause sensory input" (Friston, 2012, p.1231). Hence, as previously noted, rather than passively awaiting stimulation, the brain consistently generates predictions or 'guesses' and proactively prepares the organism to act, if necessary, prior to the arrival of stimuli, utilising past experiences and the current physiological state of the body.

For Friston and colleagues, the concept of 'value' draws heavily on Gerald Edelman's notion of 'neuronal group selection' (Edelman, 1987), which posit that the brain is fundamentally a Darwinian selective system. As Friston and colleagues (1994), explain:

> We use the word "value" with reference to neuronal responses in the following sense. The value of a global pattern of neuronal responses to a particular environmental situation (stimulus) is reflected in the capacity of that response pattern to increase the likelihood that it will recur in the same context. In this respect, value is analogous to "adaptive fitness" in evolutionary selection, where the adaptive fitness of a phenotype is defined in terms of its propensity to be represented in subsequent generations. Thus, value plays a role in neuronal selection similar to that which adaptive fitness plays in evolutionary selection. (p.230)

Throughout the processes of evolution, certain adaptive values have emerged. When these values are exemplified in specific neural structures, referred to as neural value systems, they can increase the probability of adaptive behaviours by influencing synaptic alterations within the neural circuits associated with those behaviours (Friston et al., 1994). In other words, with the assistance of neural value systems, adaptive behaviours are more likely to recur, thereby boosting the opportunity to reinforce the synaptic pathways related to those behaviours, ultimately leading to the establishment of a more stable pattern. From this perspective, the brains as “somatic selectional systems do not operate according to a predefined program or syntax, they must be constrained by evolutionarily selected biases (innate values) incorporated in the phenotype” (Friston et al., 1994, p.229). In simpler terms, our value systems determine if something is ‘good’ or ‘bad’ for us, and we then act accordingly.

That begs the question: how do they distinguish between ‘good’ and ‘bad’? As elaborated in Section 2.1.2, the distinction resides in a specific subjective experiential phenomenon – we ‘feel’ it (Craig, 2015). Our ability to’ feel’ thoughts, perceptions, motivations, intentions, or potential behaviours is fundamental to life regulation (Craig, 2015). A number of different terms have been employed in the literature to delineate this phenomenon, including ‘core affect’ (Duncan & Barrett, 2007), ‘spontaneous or homeostatic feelings’ (Damasio & Damasio, 2023), ‘ancient emotion’ (De Waal, 2019), and more broadly, ‘feeling’ (Craig, 2015). Antonio and Hanna Damasio (Damasio & Damasio, 2023) have recently argued that homeostatic feelings “arise from the uninterrupted process of life regulation and correspond to both salient physiological fluctuations such as hunger, pain, well-being, or malaise, as well as to states closer to metabolic equilibrium and best described as feelings of life/existence” (p.1). This phenomenon is viewed as essential for all mental experiences (Barrett, 2017; Carvalho & Damasio, 2021; Damasio & Damasio, 2023; Duncan & Barrett, 2007). For example, Damasio and Damasio (2023) assert, “homeostatic feelings were the inaugural phenomena of consciousness in biological evolution … The “knowledge” carried by conscious homeostatic feelings provided “overt” guidance for life regulation, an advance over the covert regulation present in nonconscious organisms” (p.1). This ‘overt’ guidance manifests through two fundamental properties of core affect or homeostatic feeling: valence and arousal (Duncan &

Barrett, 2007). For instance, if an organism's value system assesses something as 'bad', this 'badness' is manifested as an enduring homeostatic feeling of displeasure (valence) and agitation (arousal).

Given homeostatic feelings "arise from the uninterrupted process of life regulation" (Damasio & Damasio, 2023, p.1), it fundamentally connects the body and the brain. As previously noted, Bayesian brains are constantly "trying to infer the causes of our sensations based on a generative model of the world" (Friston, 2012, p. 1231), where they strive to minimise prediction error. These processes involve intricate connections among the cortex, subcortex, and body. Notably, thalamic nuclei play a crucial role in the ongoing integration of bodily information into these processes (Miller & Clark, 2018). These subcortical loops influence precision estimations based on bodily states and actions, allowing values of considerable importance to the organism, along with homeostatic feelings related to interoceptive bodily states, to continuously shape high-level predictions (Miller & Clark, 2018). These predictions, in turn, influence bodily states and actions as they unfold (Miller & Clark, 2018).

In conclusion, the connectivity among the cortex, subcortex, and body constitutes the mechanism that enables the Bayesian brain to perform the processes of prediction, prediction error, and action. The value system facilitates the Bayesian brain's selective choice of particular inputs or behaviours to satisfy adaptive requirements. The value system's judgment of specific inputs or behaviours as 'good' or 'bad' is manifested through core affect or homeostatic feelings. This thesis posits that these processes occur in children's brains when interacting with their peers and experiencing inclusion and exclusion in their school contexts. Their past experiences form the basis of a new prediction at the interface of potential exclusion from another child, and the actual event will either confirm or reject the prediction, influencing the brain's prediction of a future event. However, the traditional educational research methods, mainly relying on behavioural or self-report measures, mostly miss this brain's prediction (anticipatory process) and unspoken emotional experiences in their analysis (Kim et al., 2025). To capture these critical aspects involved in children's experience of social exclusion, the design of this study includes the collection of EEG data, and it was triangulated with other types of data yielded from conventional educational research methods.

1.4 ERP components and the anticipation and post hoc feedback appraisals of social exclusion

The present study employed EEG and ERP technology to elucidate the neural dynamics associated with the experiences of individuals subjected to social exclusion. EEG is defined as "a brain imaging technique that detects electrical activity in the brain using small metal discs (electrodes) attached to the scalp" (Kim & Sankey, 2022, p.9). This non-invasive technology renders EEG particularly advantageous for research involving young children (Kim et al., 2025). In this study, ERP component data was extracted to examine the emotional dynamics associated with social exclusion within this demographic. ERP is characterised as "a time-locked electrophysiological response to a specific event" (Kim & Sankey, 2022). By extracting ERP components from the raw EEG data, this study was able to analyse the specific electrical responses linked to particular events within the context of social exclusion. Chapter 2 will outline the specific ERPs investigated in this project to probe distinctive phases of neural processes, which include Stimulus Preceding Negativity (SPN), Feedback-Related Negativity (FRN), P3, and Late Positive Potential (LPP).

These ERPs can be classified into two distinct phases based on their timing concerning specific stimuli or events: the anticipatory phase (prediction phase) and the post-hoc feedback appraisal phase (prediction-confirmation/error appraisal phase). The SPN is observed before the stimulus onset indexing process from the anticipatory phase, while the other ERPs are observed after the stimulus presentation indexing processes involved in the post-feedback phase. The specific event examined in this study concerned peers' social feedback, representing social acceptance or rejection. Therefore, within the parameters of this research, the SPN, emerging prior to peer's feedback, encapsulated the anticipation of such feedback. In contrast, other ERPs, including the FRN, P3, and LPP, arose after the reception of feedback, reflecting various neural processes linked to post hoc feedback appraisal. The forthcoming chapters will explore the intricacies of each ERP and their respective underlying neural mechanisms in more detail. Nonetheless, it is imperative at this juncture to recognise that through the purposeful selection of these ERPs that occur both pre- and post-feedback onset, a thorough analysis of two pivotal phases in the victim's experience of social exclusion can be conducted: the anticipatory phase and the post-feedback evaluation phase. This analysis is essential in addressing the research questions outlined in Section 1.6, below.

When developing the research design for this study, a methodological decision was taken to focus the EEG study exclusively on children experiencing exclusion from *unfamiliar* peers. This makes the study ethically viable (in not using real-life photographs of known children) and, importantly, it also enables the researcher to assess the extent of the positive impact a child's sense school belonging might have beyond the everyday familiarities of the school environment and known peers. As noted above, it is already well documented that a child's sense of school belonging has positive impacts on their academic achievements and their overall wellbeing at the school. But the question arise whether these positive impacts on achievement and wellbeing are replicated beyond the school, especially when experiencing exclusion from other similar-aged children who are not familiar?

1.5 The three main objectives of the study

Panksepp (1998) posited that “a comprehensive discussion of emotions must pursue a difficult triangulation - considering affective experience, behavioural/bodily changes, and the operation of neural circuits” (p. 34). The present study embodies this principle. However, as noted in Section 1.7 (below) regarding the significance of this study and further elaborated in Section 2.3, we take Panksepp’s advice a step further by devising a new conceptual framework for the investigation of social exclusion that not only recognises the importance of triangulating information from multiple levels, it also emphasises the brain’s predictive capacity. Furthermore, it incorporates ‘real-time’ and ‘here-and-now’ interactions among components at both individual and contextual levels as children engage with social environments (e.g., peers, classroom routines) by integrating the ‘feedback loops’ (Kim & Sankey, 2022, p. 242) as a fundamental process.

Given the new conceptual framework, this study aims to accomplish three main objectives. First, to provide a critical analysis of both traditional and contemporary research surrounding social exclusion, bearing in mind recent advancements in neuroscience, including those related to emotion and emotional development and the embodied and physically, socially, and culturally embedded, predictive brain. It is believed this analysis will provide a sound basis for researching how young children emotionally experience social exclusion and the subsequent impacts of these emotions on their overall well-being. Secondly, to clarify the neural dynamics that underlie the *anticipation* of social feedback and *subsequent feedback appraisal*, and to investigate the correlations between these neurophysiological measures and self-reported distress associated with social exclusion, together with the individuals’ sense of belonging within their educational context. This investigation will be a school-based empirical multimodal study, employing EEG/ERP methodologies and traditional methods such as self-report questionnaires and interviews, informed by the existing literature. Third, to investigate the implications of this empirical research for identifying effective intervention strategies in response to social exclusion in primary school and assist primary school children in coping with the emotional experience of social exclusion.

1.6 Research Questions

Given these three objectives, this study will attempt to answer three research questions, namely:

Research Question 1: What emotional experiences do young primary school children, aged 6 to 8 years, encounter when faced with social exclusion from other children, and how might these experiences influence their well-being?

Research Question 2: What neural dynamics are involved in predicting and appraising social exclusion perpetrated by unfamiliar peers, and how do real-time neural processes correlate with a child's self-reported responses regarding immediate distress from social exclusion, and their sense of school belonging?

Research Question 3: What insights can be gained from the findings of multimodal data regarding the most effective strategies to assist primary school children in coping with the felt social and emotional consequences of social exclusion?

1.7 Significance of the study

This study is significant and innovative in developing a novel conceptual framework for the investigation of social exclusion that is founded on quite recent insights into how emotion and cognition are inherently interwoven in the brain, drawn from contemporary neuroscience and the science of dynamic, complex systems (which exemplifies the brain, *par excellence*), which aims to shed new light on the nature of social exclusion, particularly the experience of being a victim of social exclusion in primary school settings.

This framework is innovative in transcending most traditional linear (and often dichotomous) accounts of emotion and cognition, and in establishing a philosophically robust and neurobiologically sound alternative, founded on the neurobiology of the homeostatic and interoceptive brain (Damasio, 2012, 2018; Barrett, 2017). This alternative emphasises the nonlinear, self-organising dynamics of emotion and cognition (Thelen & Smith 1994), and is comprehensive, holistic, and innovative in underscoring the importance of 'value' within the brain's recursive synaptic processing processes (Edelman, 1987; Friston, 2012), and encompasses the notion of the Bayesian predictive brain (Friston, 2012; Clark, 2016) and the Prediction-Feedback cycle (Kim & Sankey, 2022). Significantly, though these increasingly accepted theories in neuroscience and the science of dynamic, complex systems have been taught in teacher education at the University of Sydney for the past fifteen years, elsewhere in Australia, in the field of education, they remain largely unknown and, though arguably, starting to gain global recognition in education, hitherto they have not been applied in studying social exclusion in school.

This study is also significant and novel in employing temporally high-resolution EEG brain imaging techniques, an advanced ERP methodology, and Mixed Effects Model (MEM) statistical analysis. Although these techniques and technologies are now widely used in mainstream psychology, they are seldom if ever used by education researchers. Even when such research exists, usually in conjunction with colleagues in mainstream psychology, it is usually conducted in a laboratory and seldom if ever carried out within school environments. This study is therefore particularly noteworthy as it probes the social exclusion experienced by individual students within an ecologically valid (methodologically) and educationally relevant context, while simultaneously recording real-time neural correlates.

The study also provides a novel and significant contribution to scholarship by adopting a cross-modal methodological approach that integrates conventional educational and neuroscientific levels of analysis to investigate social exclusion. Traditionally, educational research has relied heavily on self-report measures (Immordino-Yang & Christodoulou, 2014), operating under the assumption that people "can directly introspect" their feelings and thoughts (Kim & Sankey, 2022, p. 25). However, this overlooks the subconscious nature of much human thought that is not available to conscious introspection (Sankey, 2006). This study was novel and innovative in employing EEG/ERP technology to capture early SPN and feedback related ERPs that are subconscious processes that occur when a student experiences social exclusion in real-time. Adopting a cross-modal approach for this study also helped to avoid what is often referred to as a '*street-light bias*'- searching for something where it is easiest to look but least likely to be found (Florio-Ruane, 2002), which confuses some otherwise well-intentioned educational research and can result in an underestimation of children's abilities (Kim et al., 2025).

It is believed the triangulation of multimodal data in this study yielded a more comprehensive and informed understanding of the subjective experiences of individuals who are victims of social exclusion. Specifically, ERP technology probed the real-time neural mechanisms that underlie the anticipation of social feedback and the subsequent evaluations of this feedback from the perspective of a predictive brain. Additionally, it explored the correlation between these *real-time* neural processes and self-reported feelings of distress associated with social exclusion. Furthermore, the study was significant in probing each individual participant's sense of belonging within their academic environment and how this influences real-time neural mechanisms. It is also believed that a thorough understanding of the neural mechanisms underlying the social and emotional dynamics related to social exclusion has the potential fundamentally to transform educational strategies and can pave the way for the development of programmes designed to enhance students' social and emotional learning.

The significance of this study is also manifested in its empirical research findings, which may be briefly summarised as:

1. This study corroborates much previous research showing that when being introduced to a group of similar-aged children, children exhibit an emotional desire to be accepted and to feel they belong within the new community.

2. Real-time neural processes significantly correlate with a child's self-reported responses regarding immediate distress from social exclusion, and with their sense of school belonging. A strong sense of belonging to one's own school acts as protective factor, enhancing emotion regulation and reducing distress, when threatened by unknown peer's rejection.

3. A number of insights can be gained from the findings that provide helpful cues in developing effective strategies to assist primary school children in coping with the felt social and emotional consequences of social exclusion. Strategies should encompass recognition that a child's social

prediction regarding whether they will be accepted or rejected significantly influences emotional processes in their own brain. In particular, a child's negative social expectations prohibit their sense of school belonging from exerting its protective effect.

4. Methodologically, the findings from this study confirms the merits of multi-modal research design, and the limitations of self-reported data to probe the emotional experiences that young primary school children encounter when confronted with social exclusion in school, particularly its inability to capture the nuanced relationship between children's prediction of whether they will be accepted or rejected and the social distress that follows social exclusion.

The empirical findings of this study will be presented fully in Chapter 4 and discussed in Chapter 5, wherein their innovative contributions to existing knowledge will be underscored.

1.8 The structure of the study

This thesis consists of six chapters, each intricately connected to address the three research questions outlined above and ultimately achieve the three overarching objectives of this study. This chapter has established a foundation for the subsequent chapters by emphasising fundamental concepts underpinning the research, including, among others, social exclusion as a form of existential and neurobiological harm and the embodiment of emotion within the Bayesian predictive brain. Building upon the preceding chapter, Chapter 2 conducts a comprehensive examination of relevant literature to establish a robust and sound theoretical and methodological foundation for this study. Section 2.1 highlights the emotions arising from the embodied, socially, and culturally embedded predictive brain, thereby constructing a philosophically non-reductive and neurobiologically plausible theoretical framework for emotion. This section advocates for the intrinsic interconnection between emotion and rationality and stresses the importance of emotion in enhancing students' well-being. A dynamic systems approach to learning and development, introduced by Thelen and Smith (1994), serves as the guiding theoretical framework, positing a holistic perspective on social and emotional development. Furthermore, contemporary emotion theories are examined to clarify the embodiment of emotion and the brain's predictive capacity.

Section 2.2 critically examines diverse perspectives on social exclusion, primarily drawing from the fields of education and psychology, to evaluate their merits and limitations in elucidating relational dynamics between peers and the personal experiences of victims. The review and critical dialogue presented in this section will generate substantial insights relevant to addressing Research Question 1. Building upon the biopsychosocial framework for affective processing articulated by Immordino-Yang and Gotlieb (2017), and incorporating recent insights regarding the Bayesian brain, Section 2.3 introduces an innovative conceptual framework concerning social exclusion. This framework integrates the 'here-and-now' 'feedback loops' that operate at the intersection of the predictive, embodied brain and immediate contexts (Kim & Sankey, 2022, p. 242), offering a perspective on social exclusion from a dynamic systems and predictive brain viewpoint.

The newly developed conceptual framework on social exclusion constitutes a foundational component of our research design. This school-based neuroscience investigation, predominantly structured as an experimental inquiry, was conducted at an independent school located in Sydney, Australia, with a cohort of thirty Year 2 students participating. Sections 3.4 and 3.5 provide a comprehensive elaboration on the particulars pertaining to the study participants and the methodologies employed for data collection. The data collection procedures yielded two distinct categories of information. Initially, the EEG of individual students was recorded concurrently while they engaged in the social exclusion experiment, termed the Social Judgment Paradigm (SJP), aimed at capturing the spontaneous temporal neural dynamics during the anticipation of social feedback (acceptance versus rejection) and the subsequent post-hoc feedback appraisal phase, utilising the ERP technique. Furthermore, as a triangulation strategy, the immediate emotional distress experienced following social exclusion by unfamiliar peers during the experiment was evaluated through a self-reported questionnaire administered promptly after the experiment, complemented by an interview. One week after the EEG data collection, participants' sense of belonging within their school was assessed via a self-reported questionnaire administered outside the EEG laboratory.

Chapter 4 presents a comprehensive elaboration of the results derived from the statistical analyses of the collected data. The primary findings have been organised into three distinct segments: Section 4.4 emphasises the reporting of self-reported social exclusion distress and sense of school belonging, along with their correlations; Section 4.5 delineates the prediction patterns exhibited by participants during the social exclusion experiment. Section 4.6 details the findings associated with each ERP component and its correlation with the self-reported measures. The ERP data were analysed using a Mixed Effects Model (MEM) for each ERP component. The rationale for employing MEM in the analysis of the ERP data is articulated in Section 4.6.2.

Chapter 5 presents comprehensive and well-garnered responses to the three Research Questions articulated in this study. In response to Research Question 1, Section 5.2 examines the findings related to the prediction bias exhibited by participants during the social exclusion experiment, in conjunction with the self-reported survey results concerning the immediate distress experienced following exclusion by unfamiliar peers and the daily sense of school belonging, including their interrelations. Section 5.3, in response to Research Question 2, delves into EEG findings pertinent to the anticipation processes of social feedback and post-hoc feedback appraisals, respectively. In response to Research Question 3, Section 5.4 discusses the empirical validation of our novel conceptual framework concerning social exclusion and explores the significant implications this study holds for educational practices.

Finally, in concluding this thesis, Chapter 6 synthesises the principal findings from the results of the empirical study, analyses the limitations of the current research, and proposes recommendations for future investigations.

1.9 A glossary of terms used in the study

Term	**Definition**
Allostasis/Homeostasis	The ultimate goal of all organisms is to grow, survive, thrive and reproduce, a process that requires effective regulation enabled by the brain. Efficient regulation involves the brain continuously monitoring the current state, integrating this information with its prior knowledge to optimise its regulatory decisions and satisfy the organism's needs at the least cost. This process is termed allostasis (Sterling, 2012) or homeostasis, as described by Craig (2015) and Damasio (2012).
Anticipatory process/Predictive process	The cerebral mechanism involved in anticipating social feedback after predicting it based on similar previous experiences, current physiological conditions, and contextual factors.
Brain's internal model of the world	The brain's internal model of the world comprises collections of individualised concepts that have been shaped over time through individuals' interactions with their environment.
Concept	"A concept is a collection of embodied, whole brain representations that predict what is about to happen in the sensory environment, what the best action is to deal with impending events, and their consequences for allostasis (the latter is made available to consciousness as affect)"(Barrett, 2017, p.12).

	"In the language of the brain, a concept is a group of distributed 'patterns' of activity across some population of neurons "(Barrett, 2017, p.9).
Core affect	A constant summary of an organism's neurophysiological and somatovisceral state, representing the individual's immediate relationship to the environment at a given point in time (Duncan & Barrett, 2007).
Dynamic Systems Theory (DST)	"A theoretical framework in developmental science, that focuses on the origins and self-organisation processes of novel functions" (Kim & Sankey, 2022, p. 7).
Electroencephalogram (EEG)	A non-invasive neuroimaging technique measures the spontaneous electrical activity of the brain through electrodes attached to the scalp.
Embodied brain	The concept of the embodied brain emphasises the intricate interconnections between the brain and body, highlighting the recognition that, fundamentally, the brain is about the body rather than the reverse.
Embodied emotion	The central tenet of embodied emotion is the recognition of "the significance of interoceptive awareness of feelings from the body for human awareness of emotional feelings" (Craig, 2015, p.9).
Emotion	Emotions are created by the brain, whereby bodily sensations are interpreted in relation to external environmental stimuli (Barrett, 2018, p.30). Emotions are constructed from three universal ingredients: affect, concept and social reality (Barrett, 2018).
Event-related Potentials (ERPs)	"A time-locked electrophysiological response that arises as a direct response to a specific event" (Kim & Sankey, 2022, p. 317).
Existential harm	A harm that threatens a child's healthy developmental sense of belonging and being a person of worth, in the process of becoming, developmentally.
Feedback loops	A dynamic and recursive loop between the embodied brain and its environment, wherein the brain makes predictions and updates its internal model in order to continuously minimise prediction error.
Feedback Related Negativity (FRN)	A frontocentral negative component that peaks around 250 milliseconds after feedback onset, indicating the brain's feedback monitoring.
Free energy	"An information theory measure that bounds or limits (by being greater than) the surprise on sampling some data, given a generative model" (Friston, 2010, p. 127).
Interoception	"The sensory representation of the physiological condition of all tissues and organs of the body" (Craig, 2015, p.304).
Interoceptive awareness or bodily awareness	"The capacity to report the condition of the body" (Craig, 2015, p.304).
Interoceptive sensorimotor system	"A system that integrates input that relates all aspects of the physiological condition of the body in order to control smooth muscle, cardiorespiratory activity, and autonomic and homeostatic functions, including motivated behaviour;

	in textbooks, particular portions are called the “visceral” system” (Craig, 2015, p.304).
Limbic system	“A set of subcortical brain structures including the hippocampus, amygdala, thalamus, hypo-thalamus, fornix and cingulate gyrus” (Kim & Sankey, 2022, p. 318).
Late Positive Potential (LPP)	A positive deflection in ERP waveform that arises approximately 400 milliseconds (ms) or later following the onset of significant stimuli. It is particularly well-suited for the assessment of affective processes, as it serves as an indicator of prolonged attention directed towards emotional content.
P300/P3	A positive deflection in the ERP waveform occurs approximately 300 milliseconds after the stimulus onset.
Perceptual categorisation	“The selective discrimination of an object or events from other objects or events for adaptive purposes” (Edelman, 1992, p.87).
Predictive brain	“A theory of brain function in which the brain constantly makes refined predictions about the environment” (Kim & Sankey, 2022, p. 275).
Prediction error	“A discrepancy of mismatch between the predictions produced by a brain and reality” (Kim & Sankey, 2022, p. 275).
School belonging	The concept of school belonging denotes a particular form of belonging that pertains to students’ subjective perceptions of being accepted, respected, included, and supported within their school community (Goodenow & Grady,1993).
Social reality	Social reality possesses two requisites: collective intentionality - agreement of the existence of a concept by a group of people; language (Barrett, 2018). These two abilities firstly assist the formation of a conceptual system in the brain, and secondly, it facilitates cooperative categorisation among people and allows us to communicate and influence each other (Barrett, 2018).
Social exclusion	In school settings, social exclusion has been characterised as peer group rejection or defined in terms of peers’ exclusionary behaviours (Ladd & Kochenderfer-Ladd, 2016). Social exclusion has also been defined as a form of relational bullying that can manifest in overt and covert forms (OECD, 2019). In this thesis, while focusing on peer social exclusion, the term ‘social exclusion’ will be used to encompass a broad spectrum of exclusionary events, whether deliberate or unintentional.
Stimulus-Preceding Negativity (SPN)	An ERP component that frequently reflects the anticipation of stimuli, particularly those with emotional or motivational valence or uncertainty.
Social prediction	Children’s prediction of acceptance or rejection feedback from the unfamiliar peers in the social exclusion experiment.

Theory of Neuronal Group Selection (TNGS)	A proposition concerning brain function, proposed by Gerald Edelman in 1987, which underscores the importance of value and salience in the establishment and subsequent alterations of synaptic connections and synaptic maps.
Value	Within Edelman's TNGS, the word 'value' refers to "evolutionarily derived constraints favouring behaviour that fulfil homeostatic requirements or increases fitness in an individual species" (Kim & Sankey, 2022, p. 72)

Chapter 2 Literature Review

As outlined in Chapter 1, this study has three main objectives, the first being to provide a critical analysis of both traditional and contemporary research surrounding social exclusion, bearing in mind recent advancements in neuroscience, including those related to emotion and emotional development and the embodied and physically, socially, and culturally embedded, predictive brain. This objective closely relates to Research Question 1 and the first part of Research Question 2. Together, this objective and these research questions will mainly be addressed with close reference to the literature reviewed in this chapter.

Examining the mechanisms of emotions and emotional development, both broadly and specifically concerning social exclusion, was also crucial for informing the design of this multi-modal study. This Chapter (Section 2.1) begins by critically reviewing past and prevailing views of emotion in psychology, with the aim of considering how these views might hinder progress in understanding the theoretical foundation of children's emotional experiences. It will be followed by a discussion of new perspectives that have clear benefits for educational research. The second part of the literature review (Section 2.2) will critically evaluate the merits and limitations of various established theories of social exclusion. Building on these discussions, Section 2.3 proposes a novel conceptual framework underpinning the current investigation into social exclusion within educational contexts. Finally, Section 2.4 will introduce the use of EEG/ERP technology to explore the conscious and subconscious dynamics of emotion that relate to social exclusion and review specific findings from EEG/ERP studies in this area.

2.1 Emotion in education and social development

This section aims to review literature that relates to the fundamental tenet of this study, namely, that all mental experience, including emotion, emerges from the embodied, socially, and culturally embedded predictive brain. Once a thorough introduction into this principle has been conducted, a discussion will follow on the critical merits of incorporating this tenet into educational research, especially regarding emotional and social development, such as this study on social exclusion. This section will start with a critical review of the prevailing views of emotions in psychology, with the aim of clarifying how these views may hinder progress in educational research on children's emotional and social development (Section 2.1.1). Following this, Section 2.1.2 will introduce Dynamic System Theory (DST), focusing on emergent self-organisation, which is a core principle of DST. It will then discuss the embodied and predictive brain and its relevance in enhancing our understanding of emotion.

2.1.1 Problems of emotion theories in developmental and educational research

Thelen (1992) identified three significant and enduring inquiries prevalent in any specific domain of developmental study: the question of *origins*, the levels of *causality*, and the nature of *variability*. The domain of *variability* encompasses two forms, variability within the same individual across different contexts and variability among distinct individuals' pathways leading to the same overall outcome. These significant and enduring inquiries remain a focal point in the study of emotional development. Researchers in the field of emotions employ diverse and often conflicting theoretical perspectives in response to these three fundamental questions. For example, James Gross and Lisa Feldman Barrett (2011) offer their comparison and contrast across distinct emotion theories that can be categorised into broad four classifications: 'basic emotion theory', 'appraisal theory', 'psychological construction theory' and 'social construction theory'. They concisely summarise several core assumptions associated with these theoretical perspectives, as illustrated in Figure 2.1.1.1. The authors assert that scholars who adopt these diverse theoretical frameworks largely concur on two fundamental points: "Emotion refers to a collection of psychological states that include subjective experience, expressive behaviour (e.g., facial, bodily, verbal), and peripheral physiological responses (e.g., heart rate, respiration)" and "Emotions are a central feature in any psychological model of the human mind" (Gross & Barrett, 2011, p. 9). Beyond these two points of consensus, virtually every other aspect of emotion remains open to further scholarly discussion (Gross & Barrett, 2011).

	Basic	*Appraisal*	*Psychological construction*	*Social construction*
1. Are emotions unique mental states?	Yes	Yes	No	Varies by model
2. Are emotions caused by special mechanisms?	Yes (e.g., affect programs)	Varies by model	No (basic ingredients vary by specific model)	No
3. Is each emotion caused by a specific brain circuit?	Yes (subcortical circuit for each emotion)	No	No (distributed brain network for each ingredient)	No
4. Do emotions have unique manifestations (in face, voice, body state)?	Yes	Varies by model	No	No
5. Does each emotion have a unique response tendency?	Yes	In most models	No	No
6. Is experience a necessary feature of emotion?	Varies by model	Yes	Yes	No
7. What is universal?	Emotions are universal	Appraisals are universal	Psychological ingredients are universal	Influence of social context is universal
8. How important is variability in emotions?	Epiphenomenal	Varies by model	Emphasized	Present, but not central
9. Are emotions shared with non-human animals?	Yes	Some appraisals are shared	Affect is shared	No
10. How did the evolution shape emotions?	Specific emotions evolved	Cognitive appraisals evolved	Basic ingredients evolved	Cultural and social structure evolved

Figure 2.1.1.1 Core assumptions of four theoretical perspectives

(Gross & Barrett, 2011, p. 9)

The four categories of emotional theories proposed by Gross and Barrett (2011), in conjunction with the three fundamental inquiries recommended by Thelen (1992), establish a comprehensive evaluation framework for discussion in this section. This section will concentrate on the critical examination of ‘basic emotion theory’, ‘appraisal theory’, ‘functional theory’ and ‘social construction theory’ alongside personal trait theories, as these theoretical frameworks bear traditional perspectives on emotion and are frequently adopted in educational research. Although functional and personal trait theories were not explicitly discussed in the paper by Gross and Barrett (2011), they exert considerable influence within the educational field and thus merit acknowledgment in this context. Barrett’s psychological construction theory of emotion will be elaborated upon in Section 2.1.2, as this perspective encapsulates the contemporary understanding of the brain as an embodied, socially, and culturally embedded predictive entity. The discussion surrounding traditional emotion theories will focus on the three inquiries posited by Thelen (1992) (see Table 2.1.1.1). What is the significance and relevance of discussing these fundamental inquiries from diverse psychological perspectives related to emotion within an educational context? To provide a direct response, the theoretical perspectives and their underlying beliefs regarding these three inquiries will significantly influence educational research and practice concerning emotional and social development in various ways, as discussed below.

Table 2.1.1.1 Overview of the limitations of traditional emotion theories

<table>
<tr><th>Traditional emotion theories</th><th>Origins of emotion</th><th>Level of causality</th><th>Nature of variability</th></tr>
<tr><td>Basic emotion theory</td><td>Assert that specific emotions correspond to a unique array of neurophysiological processes, observable expressive responses, and internal phenomenological experiences.</td><td rowspan="3">Assume a simplistic, linear causation between emotion and cognition, thereby highlighting overarching constructs such as appraisal, trait, and perception.</td><td rowspan="5">Various factors and individual differences are often treated as extraneous noise in the data, leading to their dismissal</td></tr>
<tr><td>Appraisal theory</td><td>An individual's interpretation of events is crucial in eliciting and distinguishing emotions.</td></tr>
<tr><td>Functional approaches</td><td>Characterise emotions as adaptations to the challenges of social and physical survival, emphasising their beneficial outcomes</td></tr>
<tr><td>Trait theory</td><td>Focus on exploring the relationship between emotions and various personality traits</td><td rowspan="2">Adopt a dichotomous view that emphasises the dualism of emotion and cognition, the mind and body, the organism and its environment, among other dimensions</td></tr>
<tr><td>Social construction theory</td><td>Some assert that social configurations act as catalysts for fundamental emotional responses, while others conceptualise emotions as products of sociocultural influences and human construction rather than as innate responses.</td></tr>
</table>

The origins of emotion

The origins of emotion have been a subject of extensive discussion within the field, examined through various theoretical perspectives over the years. Proponents of basic emotion theory assert the existence of a limited set of discrete emotions, emphasising a general consensus that each discrete emotion is associated with "a unique corresponding set of neurophysiological processes, observable expressive responses, and internal phenomenological experiences" (Camras & Witherington, 2005, p. 331). Basic emotion theory significantly impacts academic research, as shown by the extensive agreement among scholars that specific emotions can be reliably identified through facial expressions (Barrett, 2018). A particularly relevant area of educational research that utilises the basic emotion approach is the development of Social and Emotional Learning (SEL) programmes in schools. For example, Lawson and colleagues (2019) systematically analysed the essential components present in fourteen evidence-based SEL programmes tailored for elementary schools. Their findings indicated that 'Identifying Others' Feelings', one of the five fundamental components, was consistently evident across all examined SEL programmes. Moreover, within the practices associated with Identifying Others' Feelings, the predominant indicators identified include the interpretation of emotions through facial expressions, body language, and contextual factors, noted in 100% of the reviewed programmes (Lawson et al., 2019). Consequently, each of the fourteen reviewed SEL programmes aimed at elementary school students encompasses elements specifically designed to educate students on recognising distinct emotions through facial expressions and contextual situations. However, several scholars have raised concerns regarding the reliability of using facial expressions to differentiate distinct emotions. For instance, Barrett (2018) contends that many studies on facial expressions rely on stereotypical photographs of emotions portrayed by professional actors, which skews the results concerning emotion recognition across different cultures. Additionally, the photographs employed in numerous facial expression studies frequently included emotional words or narratives, and removing these cues led to significantly reduced recognition rates (Barrett, 2018). This methodology has resulted in misleading conclusions concerning the universality of emotions, considering that individuals from diverse cultural backgrounds can generally recognise the emotions portrayed in these images when supplemented with emotional cues (Barrett, 2018). Hence, she asserts that the emotional concepts (delineated in Section 2. 1. 2) enhance recognition in these studies rather than the facial expressions (Barrett, 2018).

Appraisal theories argue that the individual's interpretation of events, rather than the events themselves, is pivotal in eliciting and distinguishing emotions (Fernando et al., 2017; Scherer, 2009). While acknowledging the importance of cognitive evaluations, these appraisal theories tend to adopt the linear 'input-appraisal-output' perspective inherent in traditional cognitivism, which is now known to be outmoded. Also, this theoretical perspective may establish a constrained emphasis on how a child internally interprets the exclusionary event, potentially overlooking the broader social context where the appraisal is situated. Cultural norms and peer group power dynamics significantly influence how children comprehend and react to exclusion. Concentrating exclusively on the child's internal cognitive appraisal may overlook various factors that contribute to their experience of social exclusion, including "personality traits, religion, immigration status, ethnicity, nationality, gender, and adherence to or deviation from group norms" (Hitti et al., 2011, p. 597).

In contrast, functional approaches characterise emotions as "adaptations to the problems of social and physical survival" (Keltner & Gross, 1999, p. 470), highlighting their advantageous outcomes (Keltner & Gross, 1999). However, this approach also possesses limitations in elucidating the emotional dynamics associated with social exclusion. For instance, social exclusion can lead to feelings of anger, which, in turn, is associated with antisocial behaviour (Chow et al., 2008). From a functional perspective, negative emotions such as anger may be regarded as disruptive rather than adaptive, as they often lead to antisocial behaviours. Nonetheless, findings from the same study indicated that individuals who were unjustly excluded were more prone to engage in antisocial behaviour compared to those subjected to fair exclusion (Chow et al., 2008). Concentrating solely on the adaptive functions and immediate effects of emotions may yield a constrained understanding of their intricate impacts within the context of social exclusion. Furthermore, an exclusive focus on immediate functions may obscure the enduring repercussions of social exclusion on a child's emotional development and overall well-being, including the adverse effects delineated in Section 2.2.

Generally, trait researchers focus on exploring the relationship between emotions and various personality traits, including personality attributes (Izard et al., 1993; Watson & Clark, 1992) and psychological disorders such as anxiety (Mathews & McLeod, 2002). It has been proposed that individuals with varying levels of trait emotionality may exhibit differing responses to identical emotional stimuli or events (Mathews & McLeod, 1994). Although theories concerning individual traits substantially improve the comprehension of individual differences and their influence on emotional development, an excessive focus on particular traits may lead to the labelling of children—a common problem within educational institutions. Such labelling can subsequently result in varied interpretations of the behaviours exhibited by children, as perceived by both peers and educators. For example, a recent study has demonstrated that young children tend to employ traits such as kindness and unkindness to clarify the behaviours of others; this tendency appears to intensify with age (Boseovski & Lapan, 2021). Consequently, a child designated with a label may experience differential treatment, which can reinforce the characteristics or behaviours associated with that label and impede their social and emotional development. This concern is particularly pronounced in the context of social exclusion, where a child identified as 'unkind' may face increased isolation, further solidifying detrimental patterns and restricting opportunities for positive growth.

Finally, the social constructionist perspective on emotion conceptualises emotions as "social artifacts or culturally prescribed performances that are constituted by sociocultural factors and constrained by participant roles as well as by the social context" (Gross & Barrett, 2011, p. 11).

Certain models of social construction, particularly within psychology, assert that social configurations serve as catalysts for fundamental emotional responses, akin to earlier appraisal models, which position appraisals as cognitive triggers for basic emotions (Gross & Barrett, 2011). Conversely, alternative models within this paradigm conceptualise emotions as products of sociocultural influences and human construction rather than as *innate* responses. This perspective posits that emotions represent cultural performances rather than mere internal mental states (Gross & Barrett, 2011). According to the social construction viewpoint, classifying a socially constructed event as an emotion, as opposed to a different psychological phenomenon, is contingent upon the social outcomes it generates (Gross & Barrett, 2011). From a social construction perspective, emotions are neither innate nor universal but are learned through social interactions and cultural norms.

The social construction perspective, which emphasises the impact of external social factors in the construction of emotions, may not sufficiently address the function of the 'embodied predictive brain' in this context, as detailed in Section 2.1.2. From the standpoint of the embodied predictive brain, the brain is not a passive responder to social stimuli; rather, it actively predicts possible future events and interprets sensory inputs, including bodily feedback, which all contribute to the emerging emotional experiences. The predominant emphasis of social construction theory on external social factors may underemphasise the importance of internal psychophysiological mechanisms in constructing emotions. More specifically, this perspective fails to acknowledge that social and cultural functions are founded upon certain essential, biologically rooted emotional processes, such as interoception and core affect, as discussed in Section 2.1.2. Therefore, although this viewpoint emphasises cultural variability, it may not adequately consider the potential interaction between biological predispositions and social learning in emotion construction. For instance, although all humans may possess a biological predisposition to feel negatively at the biological level (e.g., a sense of unease or arousal) when facing social exclusion, the specific triggers for this affective state, its intensity, and its expression can be significantly influenced by cultural norms and individual learning. Disregarding these embodied aspects may restrict comprehension of how social experiences shape children's developing brains and affect their emotional and social competencies.

This section analyses the origins of emotions through various theoretical frameworks, including basic emotion theory, appraisal theory, functional approaches, personal traits, and social constructionist perspectives. Furthermore, it highlights the limitations inherent in these traditional theories, arising from their deterministic interpretations of the origins of emotion, and how these deficiencies may impede educational research and practices related to children's emotional and social development, particularly in the context of social exclusion. The subsequent discourse will emphasise the levels of causality derived from these theoretical perspectives, which will be inextricably linked to the respective interpretations of the origins of emotion within each theoretical framework.

Levels of causality

The varied conceptualisations regarding the origins of emotion from the aforementioned traditional theories illustrate a dichotomous view that emphasises the dualism of emotion and cognition, the mind and body, the organism and its environment, among other dimensions. This dichotomous belief has increasingly faced challenges from scholars who have adopted a range of theoretical perspectives. These contemporary perspectives encompass the Dynamic System Approach (DSA) (Hollenstein et al., 2004; Lunkenheimer et al., 2012), the neuropsychological viewpoint (Barrett, 2018; Woltering & Lewis, 2009), and the neurobiological framework (Damasio, 2018; De Waal, 2019; Edelman, 1987, 1992). For instance, Lewis (2005) critiques these traditional emotion theories for generally assuming a simplistic, linear causation between emotion and cognition, thereby highlighting overarching constructs such as appraisal, emotion, and perception. Both basic and appraisal theories posit that emotion is triggered by events; however, appraisal theories maintain that it is the appraisal of these events, rather than the events themselves, that elicits and differentiates emotions (Scherer, 2009). Barrett (2017) asserts a strong disagreement with this perspective, positing that the meaning of an event arises from action, rather than being generated in reverse order. Typically, appraisal theories assert that the appraisal process dictates emotional responses, denying a causal role of emotion in appraisal processes and neglecting the fact that emotions can bias various cognitive processes, including attention, evaluation, judgment, and memory (Lewis, 2005). In contrast, functional theories propose that emotion serves as the causal antecedent of cognition (Lewis, 2005). Furthermore, the personal trait account of emotion posits that individual attributes contribute to emotional biases, concentrating on variations in the interaction between cognition and emotion while disregarding their origins (Lewis, 2005). Social construction theory frequently overemphasises the top-down impact of culture (Gross & Barrett, 2011).

This dichotomous perspective prevalent in emotion theory is also evident in educational research and practice. For instance, the Collaborative for Academic, Social, and Emotional Learning (CASEL), a leading advocate for SEL, has proposed a framework that organises the skills targeted by SEL programmes into five interrelated sets of competencies: self-awareness, self-management, social awareness, relationship skills, and responsible decision-making (Lawson et al., 2019). In a similar vein, a team of researchers at the Harvard Graduate School of Education (HGSE) published a report titled 'Navigating SEL from the inside out – looking inside & across 33 leading SEL programs: a practical resource for schools and OST providers', categorising SEL skills and competencies into six domains: "cognitive, emotion, social, values, perspectives, and identity" (Jones et al., 2021, p. 15). Furthermore, Gardner's (2011) theory of multiple intelligences, which holds substantial influence in the educational sphere, asserts that individuals possess various forms of intelligence, including linguistic, logical-mathematical, musical, spatial, bodily-kinesthetic, personal, and others.

Notwithstanding the various terminologies and methodologies employed to categorise SEL skills, or the so-called 'intelligence', these approaches ultimately illustrate a dichotomous perspective of the human mind, emphasising an artificial division between emotional and cognitive mechanisms and between the body and the mind. For instance, the aforementioned report by the Harvard Graduate School of Education further posits that the first three domains- cognitive, emotional, and social- encompass a suite of SEL skills and competencies, such as "self-regulation, executive functioning, and critical thinking skills that enable children and youth to take in and interpret information and manage their thoughts, feelings, and behaviour toward the attainment of a goal" (Jones et al., 2021, p. 15). The fundamental premises underlying statements of this nature position emotion in a subordinate role, asserting that it is an aspect of the human mind that should be regulated or controlled by cognition. Such artificial classifications of the human mind conflict with contemporary perspectives, which assert that all mental experiences arise from an embodied, socially and culturally predictive brain. The so-called 'cognition' is invariably accompanied by an affective inclination (refer to Section 2.1.2 for further details). Furthermore, this dualistic belief is also evident in educational practices; for example, SEL programmes are often implemented in schools as a distinct curriculum, separate from academic subjects. This division perpetuates a misleading dichotomy between academic and social-emotional learning, neglecting the contemporary understanding that human thought and learning are profoundly intertwined with emotional processes (Barrett, 2018; Damasio, 2012), which will be further elaborated in Section 2.1.2.

This presumed simplistic, linear causation between emotion and cognition likely emerges partly from the notion that “in psychology, we often take distinctiveness in experience as evidence for distinctiveness in process” (Duncan & Barrett, 2007, p.1201). Nevertheless, the potential existence of a phenomenological distinction between cognition and emotion cannot be simply translated into an ontological distinction (Duncan & Barrett, 2007). Instead of adhering to a simplistic linear model concerning the origins of emotion, contemporary perspectives predominantly acknowledge that emotion constitutes a multidimensional phenomenon arising from dynamic interactions among neural, physiological, and psychological processes within a broader social context. Consequently, the interplay of various factors is characterised by complexity rather than mere linear causation. In this context, the enduring debates surrounding ‘nature’ versus ‘nurture’, ‘cognition’ versus ‘emotion’, and ‘mind’ versus ‘body’ no longer maintain the significance they once held in numerous traditional theories of emotion. This dichotomous viewpoint, which relies on oversimplified linear causation endorsed by many traditional theories, is, at best, inadequate, if not completely incorrect. Such a deficient, misleading perspective in educational research and practice poses potential risks and detriments. A notable illustration within educational research and classroom practice is the separation of emotion and cognition, as though they constitute two distinct and concrete entities. This is evident in the extensively adopted SEL programmes within educational institutions, alongside the incorporation of Gardner’s multiple intelligence theory in educational research and practice, as previously articulated.

Variability

Concerning variability, conventional developmental studies, while seeking the innate origins and universality of development, generally neglect individual differences in emotion. This oversight can be partly attributed to the cross-sectional designs often employed in such research (Thelen, 1992). Within this framework, investigations typically aim to identify universal and representative patterns of emotional development by comparing variances among groups. Various factors and individual differences are often treated as extraneous noise in the data, leading to their dismissal. Furthermore, the failure to acknowledge variability is also evident in several traditional theories of emotion. For instance, as previously articulated, basic emotion theories underscore the existence of a specific set of discrete emotions. Most basic emotion models assert that "each emotion is caused by a dedicated mechanism (a definable brain circuit or affect program) that produces a coordinated package of experiences, response tendencies, expressive behaviours (e.g., facial expressions), and autonomic and neuroendocrine responses" (Gross & Barrett, 2011, p. 10). However, this perspective encounters substantial challenges in adequately accounting for the variability in emotional experiences observed across individuals and cultures. As detailed in Section 2.1.2, an embodied, predictive brain perspective posits that emotions are not biologically predetermined, as articulated by many basic emotion theorists; rather, they emerge through the dynamic interaction of the brain with the body and its environment. While certain biological predispositions may exist, the specific triggers, intensity, and expression of emotions are shaped by continuous learning and predictive processes. This concept resonates with the vital neuroscience principle of 'degeneracy', which suggests that "instances of an emotion (e.g., fear) are created by multiple spatiotemporal patterns in varying populations of neurons" (Barrett, 2017, p. 3). This underscores the intrinsic flexibility and adaptive capacity of the brain. Furthermore, basic emotion theories prioritising a limited range of innate and universal emotions may result in excessively simplistic interpretations of children's reactions to social exclusion. This viewpoint may overlook the intricate interplay of numerous factors that shape a child's emotional response in these circumstances. From a predictive brain perspective, a child who is perceived as 'angry' in response to exclusion, from the viewpoint of outsiders, may be experiencing a complex blend of sadness, fear, and confusion, contingent upon their personal history and specific contextual factors within an episode of exclusion. Relying exclusively on fundamental emotion classifications risks misinterpreting children's behaviours and may impede the development of effective interventions.

From the perspective of DST (elaborated in Section 2.1.2), variability is crucial for development and emotional experiences. Even minor modifications within the system can lead to significant shifts in developmental outcomes and emotional experiences. This perspective contrasts with traditional theories that focus on identifying universal emotional categories or assume simple linear causation among various factors. In contrast, contemporary theories of emotion have increasingly raised the status of variability "from the status of noise to that of essential data" (Thelen et al., 1991, p. 32). Thus, disregarding the importance of variability and individual differences in educational research and practice may lead to detrimental outcomes. For example, critical information is often neglected in studies focusing solely on comparing group differences. In the classroom environment, educators who emphasise group averages frequently label students who do not achieve particular objectives within specified timelines as failing, without acknowledging that each student progresses at their own pace. For instance, regarding personal intelligence in Gardner's (2011) multiple intelligence theory, he posited that

> one can divide the growth of personal knowledge into a number of steps or stages. At each step, it is possible to identify certain features that are important for the development of intrapersonal intelligence, as well as other factors that prove crucial for the growth of interpersonal intelligence. (p. 258)

From this perspective, certain behaviours may be perceived as negative without recognising that such conduct may not be intrinsically harmful; rather, it could signify a child's appeal for assistance. For instance, a child who is consistently excluded by peers may exhibit aggressive behaviour as a means to rejoin a game. This behaviour exemplifies their strategy for seeking inclusion and may represent their only means of doing so. If educators assume that all children should inherently possess the ability to exhibit so-called 'appropriate' interpersonal behaviours at a specific age, those who do not meet these expectations may be hastily categorised as 'problematic'. Gardner's (2011) assertion that personal intelligence, which is intricately linked to emotional and social development, follows a stage-like linear progression contradicts contemporary perspectives, which suggest that development emerges from self-organisation within a dynamic system (refer to Section 2.1.2 for additional details on DST).

The above section briefly discussed some traditional emotion-theoretic perspectives and their underlying assumptions regarding three essential inquiries in emotion development: emotion's origin, causality level, and variability status. It also explored how these assumptions influence and hinder educational research and practice in emotion and social development. In conclusion, as mentioned earlier, many conventional emotion theories adopt a binary perspective that emphasises the dichotomy between emotion and cognition, mind and body, as well as individuals and contexts. Frequently, these theories employ a simplistic linear model to comprehend emotional dynamics and their development, disregarding the inherent variability and individual differences. Such outdated beliefs have significantly impeded educational researchers and educators in enhancing their understanding of child development and the influence of the school environment—particularly adverse experiences such as social exclusion—on learning and development. Conversely, as previously noted, contemporary conceptualisations of emotion from the embodied, socially and culturally embedded predictive brain perspective, informed by multiple different disciplines, reject this simplistic linear viewpoint of emotion and resolve the ongoing debates concerning the origins of emotion, levels of causality, and individual variability. In alignment with these contemporary perspectives, this thesis posits that no artificial distinction exists between cognition and emotion, a declaration that would fundamentally transform the assumptions prevalent in numerous traditional theories of emotion. To elaborate on this proposition, the subsequent section will primarily utilise the perspectives of biology, neuroscience, and DST to explore emotion and emotional development.

2.1.2 Emotions emerging from embodied, socially and culturally embedded predictive brain

This section underscores the significance of employing DST to conceptualise emotions as emergent self-organising systems. A concise exploration of the principle of 'emergent self-organisation', a fundamental tenet of DST, will be conducted, alongside a discussion of its relevance in the analysis of development more broadly, as well as emotional phenomena specifically. Building upon this core principle, the section will introduce the embodied and predictive brain, elucidating its critical role in enhancing our understanding of emotions. Particular emphasis will be directed towards the contributions of Antonio Damasio and Lisa Feldman Barrett within this field.

Dynamic Systems Theory (DST) and development

DST conceptualises the developing organism and its surrounding environment as a Dynamic System (DS) (Thelen, 1992). This framework appeals to numerous developmentalists as it effectively responds to several persistent debates across various developmental disciplines (Thelen, 1992). In the realm of emotion, detailed in Section 2.1.1, these ongoing debates centre on three essential questions: the origins of emotion, levels of causation, and variability. As mentioned in the prior session, several traditional theories of emotion exhibit inherent limitations rooted in these crucial inquiries. This section will illustrate how applying dynamic system principles to emotion enables educational researchers to overcome the deficiencies of conventional theories, which frequently depend on overly simplistic, linear causal models and emphasise psychological wholes rather than the dynamic interactions among individual components within the system.

To begin this discussion, we shall examine several fundamental principles of DST and their implications for development and learning within the educational sector. It is essential to articulate these principles at the outset, as DST is the foundational framework upon which numerous contemporary neuroscience theories are constructed. Furthermore, it provides a valuable framework for the current study in conceptualising the emergent nature of emotional experiences and the relationship between the individual child and multiple parts in her school environment. Subsequently, we shall offer sufficient background on key concepts, including *allostasis*, *value*, *core affect*, and *the embodied predictive brain*, before delving into contemporary emotional theories intricately associated with these concepts.

All living systems, including the human body and brain, are considered dynamic systems (Damasio, 2018; Edelman, 1992). A Dynamic System (DS) is defined as a complex, self-organising entity comprising numerous individual elements and "open to a complex environment" (Smith & Thelen, 2003, p. 343). The designation 'dynamic' underscores that the system continuously evolves over time; however, self-organisation indicates that such systems can attain relatively stable states intermittently (Lewis, 2005). Self-organisation pertains to the phenomenon where higher-order patterns or structures spontaneously emerge from recursive interactions among simpler components within the system (Smith & Thelen, 2003). DST conceptualises emotions as a dynamic system arising from the intricate interactions of multiple elements. This perspective resolves the debates surrounding the origins of emotions, emphasising their emergent properties rather than relying on fixed mechanisms commonly found in numerous traditional emotion theories.

Notably, in a dynamic system, no singular causal component is deemed more compelling than others; this concept is termed ‘multiple causality’ in dynamic systems terminology. When the external conditions of the system are altered, the system may become unstable. At these unstable points, “the system tests various configurations or collective motions of its parts by fluctuations. The size (amplitude) of some of the new collective configurations tends to increase progressively, whereas other configurations relax rapidly to certain equilibrium values” (Haken, 1987, p. 425). The increasing configurations (modes) “act as *order parameters* and are capable of *slaving* all other modes of the system” (Haken, 1987, p. 425). Hence, the dynamic system “can be described, therefore, in terms of one- or a few-order parameters, or collective variables, rather than by the individual elements. The order parameter acts to constrain or compress the degrees of freedom available to the elemental components” (Thelen & Smith, 1994, p.55). In other terms, the entire system can be governed by a few order parameters that dictate the evolving order of the system. Ultimately, a new state emerges when external conditions are further modified (Haken, 1987). Through the self-organisation process, a dynamic system reaches a temporarily stable state, which is referred to as an ‘attractor’ in DST (Lewis et al., 1999). It is important to note that the self-organising process involves both positive and negative feedback mechanisms (Lewis, 2005). Feedback embodies a type of nonlinear causation that either initiates new patterns or modifies the system through a positive feedback loop or stabilises the system and compensates for growth or change via a negative feedback loop (Lewis, 2005). The multi-causality principle in dynamic systems addresses ongoing discussions regarding the levels of causality observed in traditional emotion theories, as elaborated in Section 2.1.1.

Dynamic systems remain relatively stable at attractor states until a new attractor emerges through self-organisation (Kim & Sankey, 2010). As previously discussed, the attractor state is only reached when the system is assembled through the slaving of its order parameter; there is no predetermined program, code, or schema dictating the nature of the attractor or its trajectory (Thelen & Smith, 1994). Once a stable attractor state is achieved, it proves resilient to perturbations. However, the system remains open to change, and under different conditions, a new attractor state can emerge from self-organisation. In other words, a multi-component dynamic system can '*soft-assemble*' into other stable states, providing an enormous degree of flexibility for biological systems (Thelen & Smith, 1994). In instances of social exclusion, anger may emerge as an attractor state due to the intricate and reciprocal interactions of various factors, including an individual's current physiological condition, past experiences, and situational elements. This feeling of anger can be modified by alterations within the dynamic system. For instance, an individual may experience happiness upon re-inclusion—potentially facilitated by an educator's intervention, personal adjustments in behaviour, or an invitation to participate in an alternative group, among other possibilities. Ultimately, a change within this dynamic system permits the emergence of a new attractor state (e.g., happiness) that supplants the preceding one (e.g., anger). This scenario exemplifies the elegance of open and flexible dynamic systems, which afford opportunities for altering developmental trajectories through strategic intervention.

“As one or more components of the developing system changes beyond a particular threshold, the entire system may become reorganised in an apparent qualitative shift” (Smith & Thelen, 2003, p. 249). The shifts or discontinuities observed within dynamic systems are termed phase transitions. Throughout the course of development, these transitions exemplify the system’s evolution as it undergoes “a series of shifts between periods of stabilisation and periods of destabilisation" (Smith & Thelen, 2003, p. 249). Moreover, the whole, the attractor, emerges from its constituent parts; individual elements within the system coexist, yet no single element possesses causal precedence in generating this higher-order whole (Smith & Thelen, 2003). This indicates that a minor alteration within the system may lead to disruption and necessitate reorganisation into alternative attractor states (Smith & Thelen, 2003). Therefore, as discussed earlier, multicausality is a crucial tenet of DST (Smith & Thelen, 2003). Attractors can exhibit varying degrees of stability and instability; some are more resilient to change and even seem inevitable, while others can be easily shifted away from their preferred positions under certain conditions (Thelen & Smith, 1994). For those stable attractors consistently observed in specific circumstances, it is easy to believe they are hardwired or programmed (Thelen & Smith, 1994). In contrast, these stable attractors remain dynamic and changeable from the DST perspective, requiring only significant pushes to move them from their preferred positions (Thelen & Smith, 1994). This insight is crucial for teachers, as it provides hope in our efforts to support students in developing and making positive changes, even when some negative behaviours or characteristics seem permanent and resistant to any interventions. We need to identify the order parameters, create suitable contexts, and provide the right amount of push to allow new, desirable behaviours or characteristics to emerge under the appropriate circumstances.

In development, self-organisation manifests across two temporal scales: ‘real-time’ and ‘developmental time’ (Lewis et al., 1999). Within seconds or minutes, behaviours may converge toward an attractor resulting from self-organisation in real-time (Lewis et al., 1999). Conversely, over months and years, attractors themselves emerge and self-organise across developmental time, revealing recurrent behaviour patterns that increasingly exhibit stability and predictability (Hollenstein et al., 2004). The real-time dynamics are continuous and nested within the framework of the developmental time scale (Smith & Thelen, 2003). In reference to the prior example regarding anger within the context of social exclusion, this emotion emerges as an attractor state in real-time when an individual experiences exclusion. If anger consistently arises during these instances or frequently occurs when these individual faces social exclusion, it will eventually evolve into a more stable and enduring attractor state over the developmental timeline attributed to social exclusion. In essence, over a developmental time scale, this individual is more likely to experience heightened anger when subjected to exclusion by others.

From the dynamic systems perspective, "development can be envisioned, then, as a series of evolving and dissolving patterns of varying dynamic stability, rather than an inevitable march towards maturity" (Smith & Thelen, 2003, p.344). As discussed earlier, this discontinuous nature of change within developmental systems is conceptualised as phase shifts in DST (Thelen et al., 1991). A young developmental system may manifest as chaotic, unstable, and unpredictable, as new attractors consistently emerge and phase shifts transpire. "This sequence of complexity to simplicity to complexity captures the essence of dynamic systems whatever the material substance of the elements: simple molecules, photons, biological molecules, cells, tissues, organs, neurons, networks of neurons, organisms, or social systems "(Thelen & Smith, 1994, p. 51). Variations in attractor states are inherent to dynamically evolving systems, serving as catalysts for ongoing development (Thelen & Smith, 1994). The fluctuations are ongoing disturbances akin to noise that impact the system's collective behaviour (Thelen & Smith, 1994). Despite this noise, the system maintains its preferred behavioural patterns until the control parameters surpass certain thresholds (Thelen & Smith, 1994). Nonetheless, at critical junctures, the system may lose its stability, leading to increased magnification of fluctuations (Thelen & Smith, 1994). At these pivotal moments, fluctuations may dominate the system's dynamics, resulting in transient yet significant behavioural patterns (Thelen & Smith, 1994). As the control parameter is continuously adjusted, new attractor states emerge, facilitating the system's display of novel or altered behavioural patterns (Thelen & Smith, 1994). Consequently, the system attains stability, and fluctuations diminish once again. Therefore, when fluctuations become pronounced, they serve as predictors of critical transition points in development. At these critical junctures, variability in behavioural data may be prevalent.

Historically, researchers often dismissed variability—whether within or between subjects—as error variance, suggesting it should be excluded from data analyses (Smith & Thelen, 2003). In contrast, DST recognises variability as significant data, as it may indicate that the dynamic system is approaching a transition point (Lee, 2011). 'Noise' or varying responses within an experiment may indicate that the subject is undergoing a transition or that multiple quasi-stable or multi-stable attractors are accessible for selection (Thelen & Smith, 1994). From this viewpoint, the DST tackles the debates surrounding variability in the aforementioned traditional emotion theories. DST facilitates researchers in unravelling developmental trajectories across both real- and developmental-time scales. Ultimately, over time, attractors become more stable, and the complexity of the developmental system intensifies, indicating that development has transpired.

In the educational environment, fluctuations may manifest as behavioural regression. For instance, a student may exhibit newly adopted positive behaviours; however, due to the inherent instability of this recently established behavioural pattern and the characteristics of the dynamic system, it may intermittently revert to older, undesirable behaviours. When such occurrences transpire, educators may experience disappointment and even discouragement, perceiving the endeavour to modify this specific behaviour as an insurmountable challenge. By comprehending development as a dynamic system that undergoes phase shifts and acknowledging that new behaviours necessitate time and support to achieve stabilisation, educators can cultivate a greater sense of patience and optimism in fostering positive changes in their students. Furthermore, adopting dynamic system perspectives encourages teachers to address behavioural issues or learning difficulties from a systematic viewpoint. Most significantly, this perspective transitions from a purely cognitive approach, which many educators heavily rely on, to an understanding that students' learning and development represent a dynamic whole composed of various elements that continuously interact, resulting in growth or new learning emerging from these interactions. Exclusively depending on instructional content or 'talking to' students to facilitate learning or alter negative behaviours will prove insufficient in establishing enduring effects.

The DST approach highlights how emotions emerge through self-organisation and multicausality, offering a comprehensive framework for understanding emotion and its development. It tackles long-standing questions that traditional emotion theories struggle with, particularly concerning their origins, causality, and variability. The concepts of self-organisation and multicausality within dynamic systems address the origins of emotions and their causal levels. Emotions aren't fixed or predetermined; instead, they arise from the intricate interactions of multiple factors (Barrett, 2017; 2018), which will be further elaborated in the latter part of this section. Moreover, viewing emotions as a self-organising dynamic system accommodates a broad spectrum of emotional experiences. As Thelen (1992) noted,

> A dynamic view provides theoretical legitimacy to the rampant variability of development, both among contexts and individuals. Because dynamic systems are fluid and nonlinear, components may assemble in qualitatively different configurations even when changes in the participating elements are small. Thus, barely perceptible differences in the organism or the task environment may produce dramatic and sometimes nonpredictable outcomes. This essential nonlinearity also helps us understand the generation and maintenance of individual differences". (p. 191)

Consequently, the dynamic nature of an emotional system means that even slight initial differences in its components can yield a wide range of emotional outcomes, highlighting the distinctiveness of emotional experiences. This concept addresses the variability of emotions.

Emotions emerge from self-organising processes, manifesting as temporary attractor states in the moment or more enduring ones over an extended developmental period. This principle clarifies 'real-time' emotional dynamics and outlines 'developmental' trajectories over time. Variations or noise during attractor transitions or phase shifts often highlight critical moments in the history of individuals' learning and development. As previously stated, awareness of these fluctuations is crucial for educational research and practice. Additionally, emotional systems, being open and flexible, are plastic and responsive to new learning experiences. Regardless of how fixed or stable an attractor state may appear, there remains potential for reorganisation, providing opportunities for external support when necessary.

This section presents a concise discussion of the essential principles of DST and its relevance to educational research on learning and development, particularly in emotional development. DST offers a comprehensive framework for understanding emotions by addressing fundamental questions concerning their origins, causal relationships, and variability. It emphasises significant elements such as 'emergence',' variability' and 'multicausality'. The principle of self-organisation explains how emotions emerge from complex interactions among various elements, stabilising into attractor states and evolving through experiences over time. DST bridges psychological and neurobiological insights (Lewis, 2005), contributing to a more holistic understanding of emotions, which will be elaborated on later in this section. We will begin by examining the embodiment of the brain through several key concepts, including *allostasis*, *value*, *core affect* and the *predictive brain* in the next section.

The embodied brain

In this thesis, the concept of the 'embodied brain' is central to explaining the relationship between daily experiences, felt emotions and the sense of well-being that young school children experience. Antonio Damasio (2012) argues that "neurons are about the body, and this 'aboutness', this relentless pointing to the body, is the defining trait of neurons, neuron circuits, and brains" (p. 39). Damasio (2012) adds that "this aboutness is the reason why the covert will to live of the cells in our body could ever have been translated into a minded, conscious will" (p. 39). This notion of 'aboutness' encapsulates the essence of the *embodied brain*, emphasising the intricate interconnections between the brain and body. Essentially, the emergence and evolution of the brain are driven by the necessity to regulate life within a biological entity (Damasio, 2012). From this perspective, the brain cannot function independently of the body; its role is intricately linked to the body and caters to its needs.

For this to occur, the brain must possess awareness of the various processes occurring within the body. This awareness is dependent upon a crucial mechanism known as *interoception*, which transmits the body's internal state to the brain (Kim & Sankey, 2022) and "allows nervous systems to produce mapped representations of internal structures and events" (Damasio & Damasio, 2023, p. 281). Interoception is differentiated from exteroception, which endeavours to generate detailed representations of structures and events outside the organism (Damasio & Damasio, 2023). Interoception is ongoing and crucial in all aspects of mental life, including emotions and feelings (Barrett, 2017; Carvalho & Damasio, 2021; Damasio & Damasio, 2023). For instance, Carvalho and Damasio (2021) argued that feelings depend on the interoceptive processes, "which continuously sense chemical and anatomical changes in the organism" (p.1). Moreover, "interoceptive signals are increasingly recognised to have a pervasive (as yet incompletely characterised) impact on cognition, influencing attention and perception, guiding decision-making and shaping memory and emotion processing" (Tsakiris & Critchley, 2016, p.1). Considering the substantial role of interoception in transmitting bodily states to the brain, it is intricately connected to another vital mechanism essential for this brain-body connection: allostasis.

Allostasis

As previously mentioned, the embodied brain has evolved to manage life effectively (Damasio, 2012). The ultimate goal of all living organisms is to grow, survive, flourish, and reproduce, necessitating efficient regulation by the brain (Sterling, 2012). This effective regulation involves the brain continuously monitoring an organism's current state, integrating this information with previous knowledge to optimise regulatory decisions and fulfil the organism's needs with minimal cost (Sterling, 2012). This concept is known as *allostasis*, according to Sterling (2012), or *homeostasis*, as described by Craig (2015) and Damasio (2012). Essentially, allostasis involves the brain regulating the internal environment by anticipating physiological needs and addressing them proactively (Barrett, 2017). Inherently, allostasis relies on interoception. As Tsakiris and Critchley (2016) noted, "Interoception, as the sense of the physiological condition of the body, supports homeostatic control and allostatic adaptation, ensuring the stability of the organism and by driving behaviour through feelings such as hunger, thirst, and dyspnoea" (p. 1). Moreover, in their recent publication, Carvalho and Damasio (2021) introduce the Interoceptive Nervous System (INS), which consists of "a collection of peripheral and central pathways, nuclei and cortical regions" (p.1) that work together to create a real-time representation of the body's homeostatic state. The INS regulates the interoceptive process by detecting homeostatic changes—whether visceral or humoral—through various molecular sensors (Carvalho & Damasio, 2021). The interoceptive signals gathered from the periphery are then sent to the Central Nervous System (CNS) for further analysis (Carvalho & Damasio, 2021). Together, these structures monitor the body's state and coordinate appropriate responses (Carvalho & Damasio, 2021). In concise terms, the interoceptive system oversees the body's physiological state and regulates autonomic responses accordingly (Carvalho & Damasio, 2021); furthermore, it constitutes an essential component of allostasis.

Traditionally, homeostasis has been narrowly defined as "a nonconscious form of physiological control that operates automatically without subjectivity or deliberation on the part of the organism" (Damasio, 2018, p. 47). For instance, hormones facilitate the breakdown of stored sugars to counteract the immediate deficit of energy sources, restoring glucose levels to an optimal range (Damasio, 2018). This type of homeostasis is defined as 'basic homeostasis', distinguishing it from 'sociocultural homeostasis' that operates beyond a non-consciously guided regulatory process "to encompass the deliberate seeking of well-being" (Damasio, 2012, p. 27). The allostasis of the human brain necessitates continuous interaction between both forms of allostasis (Damasio, 2012). In sum, allostasis involves interrelated mechanisms that underlie neural, endocrine, and behavioural functions distributed throughout the body and among various brain regions (Craig, 2015). Moreover, for humans and numerous other organisms with sophisticated nervous systems, automated homeostasis remains crucial for survival, and the intricate process of homeostasis is supported by a value system within the brain.

The value system in the brain

As previously discussed, the foundational tenet of allostasis is optimising energy utilisation and acquisition. This principle is particularly significant for humans, considering that the human brain consumes 25% of total energy expenditure (Craig, 2015). Therefore, how might we evaluate whether a specific action is advantageous or cost-effective from the allostatic standpoint?

Gerald Edelman (1992) argues that evolution addresses this necessity by establishing a value system in the brain. In his Theory of Neuronal Group Selection (TNGS), Edelman (1992) posits that the limbic-brain stem system forms the basis of this value system, which possesses extensive connections to numerous bodily organs, including the endocrine and autonomic nervous systems. This system was selected early in evolutionary history to map bodily functions. Additionally, this value system, alongside various bodily organs, regulates fundamental needs and functions within the organism, such as sleep, digestion, reproductive activities, and the rates of heart and respiration (Edelman, 1992). In essence, the limbic-brain stem system primarily emphasises the mapping of the body rather than responding to myriad unexpected external stimuli from the environment (Edelman, 1992). Edelman (1992) contends that the brainstem is crucial for primary consciousness, arguing that this form of consciousness arises from the dynamic interplay between the limbic-brainstem system and the thalamocortical system, augmented by various cortical appendages. The limbic-brainstem system comprises value-laden brain structures that add an affective lens to all our mental experiences. “The limbic structure is a set of subcortical brain structures including hippocampus, amygdala, thalamus, hypothalamus, fornix and cingulate gyrus” (Kim & Sankey, 2022, p.36).

Nevertheless, this value system maintains continuous communication with the thalamocortical system, which incorporates the thalamus and cortex (Edelman, 1992). This thalamocortical system emerged later in evolutionary history to facilitate increasingly complex ‘categorisations’ of the external world and motor behaviours (Edelman, 1992). We will elaborate on ‘categorisation’ in greater detail at a later point. The interaction between the value system and the thalamocortical system enables the determination of action appropriateness by referencing an evolutionarily established biological value (Edelman, 1992). Consequently, actions that fulfil homeostatic requirements are deemed beneficial and appropriate for the individual. Thus, it is proposed that allostasis not only drives behaviour (Craig, 2015; Edelman, 1992) but also influences the evolution of consciousness (Damasio, 2012; Edelman, 1992). As Damasio (2012) states, "Consciousness did not invent biological value or the process of valuation” (p. 28); instead, it reveals this value and facilitates novel and efficient ways to manage it (Damasio, 2012). For humans, value is intrinsically linked, both directly and indirectly, to survival, as well as the quality of that survival—termed ‘wellbeing’ (Damasio, 2012). Importantly, the values within this value system are not solely determined by evolution; they also emerge from personal development. As Edelman (1992) states, “In our behaviour, we are driven by a categorical memory under the influence of dynamic changes of value. Beliefs and concepts are individuated only by reference to an open-ended environment, the description of which cannot be specified in advance" (p.152). This perspective associates our bodies with their respective contexts.

Core affect

How do values imposed by the brain, as discussed above, interrelate with children's conscious awareness, higher-order thinking and emotion? The key lies in one particular subjective experiential phenomenon – we 'feel' it (Craig, 2015). Our capacity to 'feel' our thoughts, perceptions, motivations, intentions, or potential behaviours is fundamental for analysing the physical energy costs and benefits (Craig, 2015). Indeed, this aspect is a crucial component of all our mental experiences, including emotions, consciousness, and perception (Damasio, 2012, 2018; Duncan & Barrett, 2007; Barrett, 2017). For instance, Damasio and Damasio (2023) argued that "the essence of consciousness is the identification of a particular mind with a particular organism" (p. 280) and " this knowledge is provided by the continuous experience of homeostatic feelings generated by the ongoing process of life regulation as the organism attempts to maintain operations in the homeostatic range" (p. 280). In other words, life regulation is anchored in the 'knowledge' derived from ongoing homeostatic feelings (Damasio & Damasio, 2023).

Numerous terms are found in the literature to describe this subjective phenomenon, including 'core affect' (Duncan & Barrett, 2007), 'primordial feelings' (Damasio, 2012), 'spontaneous or homeostatic feelings' (Carvalho & Damasio, 2021; Damasio, 2018; Damasio & Damasio, 2023), 'ancient emotion' (De Waal, 2019), 'basic emotion' (Panksepp, 1998; Izard, 2007), and simply, 'feeling' (Craig, 2015). For example, Duncan and Barrett (2007) define core affect as "a basic, psychologically primitive state" characterised by two key properties: valence and arousal. This phenomenon provides an ongoing summary of an organism's neurophysiological and somatovisceral state, functioning as a neurophysiological barometer that reflects our relationship with the environment at any moment and indicates the consequences of allostasis (Duncan & Barrett, 2007). In simpler terms, it signifies the quality of the body's internal state (e.g., viscera); thus, core affect is inherently constrained by the body's current condition, such as the ongoing visceral functions and their operational state (whether smooth or laboured), and profoundly influence our emotional experiences (Duncan & Barrett, 2007).

Similarly, the term 'homeostatic feelings' has been used to describe the same phenomenon. Damasio (2018) explains that homeostatic feelings "signify the overall state of life regulation of an organism as good, bad, or in between" (p.107). Furthermore, Carvalho and Damasio (2021) assert that "Feelings are mental representations of body states. Some of those body states occur spontaneously, as a result of basic homeostatic regulation" (p.1), labelling these as homeostatic feelings. Additionally, Craig (2015) argues that feeling is the *embodiment of homeostatic valuation*, proposing it "is an interoceptive construct that the brain uses to represent the overall energy costs and benefits of any actual or potential emotional behaviour; that is, homeostatic valuation, to facilitate choices that guide behaviour in the most energy-efficient manner" (p. 12). In other words, core affect or homeostatic feeling is closely tied to allostasis and reflects evolutionarily established value. Similarly, Duncan and Barrett (2007) contend that the primary function of core affect is to convert external sensory information into an internal and meaningful representation that facilitates safe navigation of the world (Duncan & Barrett, 2007). This function is accomplished through a widely distributed and functional network that connects sensory information regarding an external stimulus to its impact on an individual's internal somatovisceral state (Duncan & Barrett, 2007). Consequently, it generates a valenced mental representation of external stimuli (Duncan & Barrett, 2007).

Allostasis occurs consistently; individuals are never devoid of core affect, regardless of the brain's activity (e.g., perception, emotion, or evaluation) (Barrett, 2017).

In conclusion, it is well recognised that our inborn predilection to value manifests within our brain and body through this subjective experiential phenomenon – core affect. It accompanies all our mental experiences (Barrett, 2006; Damasio, 2012, 2018; Izard, 2007), and any psychological process utilising sensory input inherently carries an affective tone (Barrett, 2009). Therefore, core affect is regarded as a fundamental component of the mind, consciousness, and self (Barrett 2017). This observation is particularly pertinent to our subsequent discussion of social exclusion from the perspective of the embodied brain. For instance, we will examine how social exclusion fundamentally undermines a biologically ingrained value: the need for belonging, as elaborated in Section 2.2. Consequently, social exclusion is perceived as *'painful'* from a homeostatic viewpoint and manifests as a negative homeostatic feeling. In this thesis, we will use the terms 'core affect' and 'homeostatic feeling' interchangeably to refer to this phenomenon.

Traditional research methodologies, such as observation and self-reports, are insufficient for capturing the underlying mechanisms of the core affect. In this study, we will utilise EEG to monitor real-time neural dynamics during the anticipation of social feedback and post-doc feedback appraisal after feedback onset. As discussed in Chapter 3, the methodology chapter, to triangulate our EEG data, we will also collect self-reported data to evaluate the immediate distress following episodes of social exclusion by unfamiliar peers. The immediate distress, combined with real-time EEG data, facilitates a more comprehensive understanding of participants' affective states when encountering social exclusion. Moreover, we aim to assess participants' daily sense of school belonging. This aspect introduces an additional dimension to our data, allowing for a more in-depth analysis of the correlation between participants' prior experiences in school and their real-time neural dynamics captured by EEG.

The body and core affect

The constant communication between the body and the nervous system, driven by homeostatic needs, indicates that core affect, or homeostatic feelings, are rooted in neural and physiological bodily processes. The body and brain operate in concert, continuously communicating through chemical molecules and nerve pathways to construct feelings. As Damasio (2006) asserted, "feelings are a powerful influence on reason, that the brain systems required by the former are enmeshed in those needed by the latter, and that such specific systems are interwoven with those that regulate the body" (p.245). The recursive interconnections between the body and the brain, facilitated by mechanisms involving interoception, allostasis, and core affect, exemplify the dynamic system perspective delineated previously. Furthermore, the principles of the embodied brain have substantial implications for educational researchers and practitioners who strive to understand the subjective experiences of individuals who face social exclusion. For instance, the subjective experiences of those affected by social exclusion are shaped by their homeostatic feelings. Core affect reflects a person's essential judgment of bodily changes associated with social exclusion as either 'good' or 'bad' from an allostasis perspective. Thus, when analysing the experiences of these individuals, it is crucial not to overlook these fundamental aspects of an embodied brain. Furthermore, as discussed in Section 2.2, the pain associated with social exclusion activates many of the same neural pathways as physical pain. This suggests that the suffering caused by social exclusion includes not only psychological aspects but also physical ones. This observation highlights the physical effects social exclusion has on victims. According to DST, extended periods of social exclusion could interfere with homeostatic regulation, leading to potential physiological changes over a developmental time scale.

Allostasis and the Predictive Brain

As previously discussed, the ultimate goal of all organisms is to grow, survive, thrive, and reproduce, which requires effective regulatory mechanisms facilitated by the brain (Sterling, 2012). Effective regulation means that the brain continuously monitors the current state, integrates this information with prior knowledge, and optimises regulatory decisions to meet the organism's needs while minimising costs (Sterling, 2012). This is in accordance with the free energy principle of the Bayesian model of the brain, which posits that any self-organising system, like a brain, needs to optimise evidence of its existence by reducing its free energy through a model of its environment (Friston, 2012).

To cater for its allostatic requirements cost-effectively, rather than remaining inactive until prompted, the brain proactively anticipates, plans, and instructs the body to act before the arrival of stimuli (Barrett & Simmons, 2015; Clark, 2013; Sterling, 2012). "The brain is fundamentally an organ for predictive regulation of the internal milieu" (Sterling, 2012, p. 14). In line with predictive coding principles, incoming sensory information is continuously matched with top-down expectations or predictions derived from an internal model of the world (Clark, 2013). The objective is to minimise prediction error within a bidirectional flow of information (Clark, 2013). "In this context, prediction error can be regarded as free energy, such that minimising free energy is effectively the same as minimising prediction error" (Friston, 2012, p. 1233). This optimisation requires functional integration among various brain regions, with the intricate connectivity within the brain (inclusive of axonal and synaptic connections) serving as the foundation for this integration (Friston, 2012).

The Embodied Predictive Interoception Coding (EPIC) model, as proposed by Barrett and Simmons (2015), provides a comprehensive illustration of how the principles of predictive coding relate to allostasis. This model posits that the human brain houses a cohesive allostatic–interoceptive system wherein the agranular visceromotor cortices—including the mid-cingulate cortex, the anterior cingulate cortex (ACC), the posterior ventromedial prefrontal cortex (posterior vmPFC), the posterior orbitofrontal cortex, and the anterior insula—generate autonomic, metabolic, and immunological predictions. These predictions prepare the body to respond to the sensory world in forthcoming moments based on prior experiences. Concurrently, these visceromotor predictions are transmitted to another component of the interoceptive system, namely the mid-to-posterior insular cortex (the granular cortex), which modulates neuronal firing to represent expected interoceptive sensations (Barrett & Simmons, 2015). Furthermore, the mid-and posterior insula compares the predicted interoceptive signal with the actual interoceptive signals, calculating the discrepancies as prediction errors (Barrett & Simmons, 2015). Similarly, as discussed previously concerning allostasis, Carvalho and Damasio (2021) propose an Interoceptive Nervous System (INS) that allows the brain to proactively map the internal physiological landscape through neural and non-neural pathways. As a result, the body can be influenced by efferent responses from the central nervous system, "which can also formulate interoceptive predictions based on visceroceptive information and modulated by it" (Carvalho & Damasio, 2021, p.7).

When an error occurs, it prepares the system to better satisfy its needs in the next moment (Sterling, 2012). There exist three methods to minimise the prediction error: (1) The prediction errors are propagated from the mid and posterior insula to the deeper agranular visceromotor cortices, where the predictions can be adjusted before being relayed back to the mid and posterior insula, thereby minimising the subsequent prediction errors; (2) simultaneously the visceromotor regions issue the new predictions to the body to generate the predicted sensations; (3) the visceromotor circuitry can modulate how the brain attends to incoming sensory information (Barrett & Simmons, 2015). Essentially, "perception and action are tightly coupled, with both arising from the brain's hypotheses about the world and constrained by sensory inputs from the world" (Barrett & Simmons, 2015, p. 415). Similarly, Clark (2013) states, "Perception and action, …, are intimately related and work together to reduce prediction error by sculpting and selecting sensory inputs" (p.183). In other words, as we perceive the world, we are also ready to respond to upcoming stimuli with appropriate actions based on our brain's predictions. The dynamics of prediction and prediction error can be effectively captured through EEG owing to its exceptional real-time resolution. Consequently, the present study integrates EEG data collection.

Recent evidence has emerged in support of the EPIC model. A noteworthy study by Kleckner et al. (2017) substantiates the EPIC model's hypothesis, which posits the existence of a unified allostatic–interoceptive system within the brain. This research indicates that anatomical and functional connections exist between the interoceptive and visceromotor hubs in monkeys and humans, respectively. Moreover, it presents compelling evidence that this allostatic–interoceptive system encompasses both the salience and default mode networks and is domain-general (Kleckner et al., 2017). This system supports allostasis and a broad spectrum of psychological functions, including interoception, emotion, memory, and decision-making (Kleckner et al., 2017).

Furthermore, Alexander and Brown (2011) contend that the well-known error and conflict effect discussed in the literature may be reinterpreted through the lens of predictive coding. These authors propose that individual neurons generate signals that signify a learned prediction concerning the probability and timing of various potential outcomes of an action (Alexander & Brown, 2011, p. 1338). These predictive signals are suppressed when the anticipated outcome occurs as expected; conversely, neuronal activity reaches its zenith when an expected outcome fails to manifest (Alexander & Brown, 2011). Thus, this widely recognised error effect represents “a comparison of actual versus expected outcomes,” while conflict effects arise from "the prediction of multiple possible responses and their outcomes rather than response conflict per se” (Alexander & Brown, 2011, p. 1343). Signals from the medial prefrontal cortex (mPFC) are thought to signify “the unexpected non-occurrence of a predicted outcome” (Alexander & Brown, 2011, p. 1338). Similarly, Botvinick and colleagues define conflict as “the simultaneous activation of incompatible representations” or “the simultaneous activation of mutually inhibiting units” (2001, p. 630). The anterior cingulate cortex (ACC) is generally regarded as being implicated in monitoring this conflict process (Botvinick et al., 2001; Botvinick et al., 2004).

The predictive coding and Bayesian brain perspective align with the free energy principle articulated by Friston et al. (2006).

> The dynamics of perceptual inference at any level in the brain are moderated by top-down priors from the level above. This is recapitulated at all levels, enabling self-organisation through recurrent interactions to minimise free energy by suppressing prediction error throughout the hierarchy. In this way, higher levels provide guidance to lower levels and ensure an internal consistency of the inferred causes of sensory input at multiple levels of description. (p. 81)

From the perspective of the predictive brain, as previously articulated, in the context of social exclusion, an individual's predictive brain anticipates and prepares appropriate responses to impending stimuli (e.g., inclusion or exclusion) across various dimensions, incorporating both physiological and psychological actions. The stimuli arising from the external environment either affirm or modify these predictions. For instance, if an individual expects social exclusion based on past experiences in similar contexts, physiological alterations (e.g., elevated heart rate, muscle tension) and psychological reactions (e.g., feelings of anger, rumination on negative experiences) typically associated with previous instances of social exclusion will manifest before the actual experience. If this individual is eventually excluded, the external stimulus confirms the predictions, thereby validating these changes and leading to a continuation of those physiological and psychological responses. Conversely, if this individual is included, thereby altering the predictions, they may experience feelings of happiness and relaxation instead of anger, increased heart rate, and muscle tension.

In conclusion, the brain operates as a hierarchical dynamic system perpetually engaged in minimising free energy or the "suppression of prediction error" (Friston et al., 2006, p. 85). The brain's predictive mechanism is essential in this endeavour (Barrett & Simmons, 2015; Clark, 2013; Sterling, 2012). As Sterling (2012) elucidates, "the brain is fundamentally an organ for predictive regulation of the internal milieu" (p. 14).

So far, we have elucidated self-organisation as a foundational principle of DST and established the essential role of core affect in all mental experiences. Moreover, we contend that interoception and core affect involve ongoing communication between the body and the brain, driven by the need for homeostasis. We have introduced the innovative conceptualisation of the predictive Bayesian brain. Furthermore, we repudiate the widespread dualism prevalent in

Western tradition, which often favours either the body or the mind in emotional theories; instead, we advocate for an embodied perspective of emotion and cognition. The significant concepts pertaining to the embodied predictive brain discussed thus far will inform the creation of our novel conceptual framework that underpins the investigation into victims' experience of social exclusion (Section 2.3). This framework will subsequently guide the details of our study design (see Chapter 3). In order to establish the links between the concept of the embodied predictive brain and the phenomenon of social exclusion, it is essential to first examine several additional key concepts related to the predictive brain. These include the concepts of 'concept', 'categorisation' and 'social reality', along with discussions of emotion. These notions fundamentally shape our conceptual framework concerning social exclusion (Section 2.3). The ensuing discussion primarily draws from the works of several distinguished scholars, including Lisa Feldman Barrett, Gerald Edelman, and Antonio Damasio.

Concept, social reality and emotion

Barrett's (2018) construction theory of emotion asserts that all mental experiences, including emotions, are actively constructed as a result of interactions among three components: *core affect*, *concepts*, and *social reality*. The first of these, *core affect*, has been addressed in the preceding section, and here, we shall further explore the latter two fundamental components. It is pertinent to note that, for the purposes of this discussion, we will examine these elements separately; however, it is crucial to underscore that they function as an integrated predictive unit and are, in essence, inseparable at a neurobiological level.

Barrett (2006) asserts that emotions are constructed as experiences or perceptions arising from dynamic interactions within our nervous systems, which are situated within and engage with a complex array of other dynamic systems. However, as recognised in Kim and Sankey's book

(2022, p. 157), Barrett's perspective on emotion is not novel; indeed, much earlier in 1992, the dynamic systems theorist Alan Fogel and his colleagues wrote:

> We postulate that emotion is not felt experience alone, nor a pattern of neural firing, nor an action such as smiling. Emotion is the process that emerges from the dynamic interaction among these components as they occur in relation to changes in the social and physical context … From a dynamic systems perspective, coherent emotions can be conceived of as relatively stable patterns that are continually constructed by a complex and dynamic process of interaction among the components. (p.129)

Building on the EPIC model discussed previously, Barrett (2017) argues that the brain operates "an internal model that controls central pattern generators in the service of allostasis" (p. 12). This internal model functions based on prior experiences, manifesting as 'concepts' (Barrett, 2017). "A concept is a collection of embodied, whole-brain representations" (Barrett, 2017, p. 12). Concepts are not static and stored in the brain; instead, they are actively constructed as the brain continuously assembles "populations of predictions, each one having some probability of being the best fit to the current circumstances (i.e., Bayesian priors)" (Barrett, 2017, p.9). Unexpected information, or prediction error, is encoded and consolidated whenever it is anticipated to induce a physiological alteration in the perceiver's state, particularly when it impacts allostasis (Barrett, 2017). When the prediction error is minimised, a prediction is transformed into perception or experience. This transformation elucidates the reasons underlying sensory events and informs actions; essentially, "it categorises the sensory event" (Barrett, 2017, p. 12).

Concepts are cultivated through individuals' interactions with the surrounding world. Thus, the brain utilises past experiences to create categories corresponding to the current scenario, enabling appropriate action (Barrett, 2017). The brain perpetually constructs concepts and generates categories to recognise sensory inputs, infer their causal origins, and develop action plans in response (Barrett, 2017). When the internal model formulates an emotion concept, the resultant categorisation culminates a specific emotional instance (Barrett, 2017). "Categorisation means selecting a winning instance that becomes your perception and guides your action" (Barrett, 2018, p. 113). In essence, concepts render pure physical sensations meaningful (Barrett, 2017; 2018). This process resembles the conceptual categorisation posited by Edelman (1992). Unlike perceptual categorisation, which is described as "the selective discrimination of an object or events from other objects or events for adaptive purposes" (Edelman, 1992, p. 87) and emphasises processing signals from the external environment, conceptual categorisation operates internally within the brain, which "requires perceptual categorisation and memory, and treats the activities of portions of global mappings as its substrate" (Edelman, 1992, p. 125). Global brain mappings mean the brain's representation of our bodies and personal histories; therefore, categorisation based on these mappings necessarily incorporates both our bodies and past experiences (Edelman, 1992).

Along a similar vein, according to Damasio (2012), emotions are understood as actions, whereas feelings of emotion "are composite perceptions of what happens in our body and mind when we emoting" (Damasio, 2012, p.109). In other words, the feeling of emotion can be interpreted as 'the perception of the actions' (Damasio, 2012). This interpretation aligns with the conceptual categorisation employed by Barrett (2017; 2018) and Edelman (1987) to elucidate the process by which we extract meaning from information originating both internally and externally. Both Barrett (2017; 2018) and Edelman (1987) concur that categorisation is driven by context and is multidimensional. The identical physical sensation can be categorised in various ways; for example, a stomach-ache may be categorised as hunger, nausea, or mistrust, contingent upon the surrounding context. When an emotional concept such as fear is implicated, the brain categorises it as fear within that specific context. In other words, "an emotion is your brain's creation of what bodily sensations mean, in relation to what is going on around you in the world" (Barrett, 2018, p. 30). In this respect, emotion cannot be examined in isolation; rather, it arises within a contextual framework that illustrates the dynamic interactions between our internal landscape and the broader environment, encompassing a diverse array of social and cultural dimensions of our lives. This significant aspect is delineated within our conceptual framework regarding social exclusion (Section 2.3).

According to Barrett (2018), social reality constitutes the final critical component in constructing the human mind, encompassing emotions. "Emotions are social reality" (Barrett, 2018, p. 138). Through the conceptual categorisation process discussed above, we transform perceiver-independent sensory inputs from the body and the world into an instance of emotion using emotional concepts found in human minds (Barrett, 2018). "The concept imposes new functions on these sensations, creating reality where there was none before: an experience or perception of emotion" (Barrett, 2018, p. 138).

Emotion, as a social reality, possesses two fundamental requisites: collective intentionality—the consensus on the existence of a concept among a group of individuals—and language (Barrett, 2018). These two capabilities are significantly influenced by social and cultural factors. They facilitate the formation of the brain's internal model of the world and promote cooperative categorisation among individuals, thereby enabling effective communication and mutual influence. For instance, the terminology associated with emotions encourages the development of emotional concepts by intentionally categorising various physical instances into a goal-based concept. The term ‘happiness’ consolidates various examples characterised by unique interoceptive sensations, external sensory inputs, and behavioural responses. Regarding cooperative categorisation, collective intentionality necessitates the sharing of common knowledge; for example, an understanding of an emotional concept, which can be conveyed through language (e.g., using an emotion word to teach it). This signifies our ability to share emotional knowledge via collective intentionality and language. Emotional communication entails the alignment of our emotional categorisation with that of others. Moreover, these elements significantly contribute to social influence. For example, we can shape others’ interpretations of our behaviours as manifestations of anger, subsequently affecting their reactions.

How does the current discourse relate to the concepts, categorisation, and social reality associated with our new conceptualisation of social exclusion, as discussed in Section 2.3? Firstly, from the perspective of the predictive brain, the brain’s internal model of the world regarding social exclusion encompasses concepts or prior experiences related to social exclusion, significantly influencing the real-time physiological and neural responses encountered during subsequent instances of social exclusion. Secondly, emotions as constructs of social reality are constructed in real-time when perceiver-independent sensory input is categorised into instances of emotion (Barrett, 2018). This element will be represented in the Prediction-Feedback cycle within our framework. Furthermore, the notion of social reality carries substantial implications concerning social exclusion. For example, collective intentionality may lead to the establishment of group norms. As elaborated in Section 2.2, individuals who do not adhere to these established norms may experience exclusion from their peers. Additionally, children lacking the requisite language skills necessary for understanding and articulating shared knowledge within a social group are at an increased risk of social exclusion.

2.2 Social exclusion: View from above and below

In this section, we return to our focus on 'social exclusion' in schools, a relational and social context that poses significant threats to children's emotional well-being. Social exclusion and similar anti-social behaviours have been a focus of academic investigation across various disciplines, including education, psychology, sociology, and primatology. This section will examine different perspectives on social exclusion, primarily from those of education and psychology, to discuss their merits and limitations in explaining relational dynamics within schools and victims' personal experiences. Initial attention will be directed towards the following inquiries: What constitutes social exclusion? Why do we exclude others? How do individuals affected by social exclusion experience this phenomenon? What is the significance of context in relation to social exclusion? Following these initial inquiries, we will examine social exclusion in schools and its impact on students' sense of belonging, well-being, and academic performance. Ultimately, the critical appraisals of models of social exclusion available in educational and developmental research will contribute to establishing an enriched framework for understanding social exclusion. Particular attention will be given to the common problems across four popular models of social exclusion: the Temporal Model of Ostracism (William, 2001), the Multi-Motive Model (Richman & Leary, 2009), the integrative social-cognitive developmental perspective (Killen & Rutland, 2011), and the Transactional Model for Adaptation to Peer Rejection (Sandstrom & Zakriski, 2004).

2.2.1 What is social exclusion: The issues of definition

In psychological studies, various terminologies are utilised interchangeably to refer to exclusionary behaviours among members of society, including 'ostracism', 'rejection' and the term 'social exclusion' itself. The term 'ostracism' has its origin in 500 BC, when citizens of Athens used *ostraca*, pieces of pottery, to vote on whether a member of society, typically a political leader, should be exiled or not. Today, the act of 'ostracism' is still pervasive in the political arena (e.g., ostracised Prime Minister), but the term 'ostracised' is also applied in non-political and informal contexts, referring to the phenomenon of "being ignored and excluded, often without excessive explanation or explicit negative attention" (Williams, 2007, p. 429). The term 'rejection' generally entails "an explicit declaration that an individual or group is not wanted" (Williams, 2007, p. 427); therefore, it shares similar meanings with the political action of 'ostracism'. However, in psychological literature, 'rejection' describes instances "in which people perceive that their *relational value* is lower than they desire" (Leary, 2005, p. 47), giving more acknowledgement to how the outcome of exclusion may be perceived by those excluded. In this context, *relational value* is characterised as "the degree to which they believe that others value having relationships with them" (Richman & Leary, 2009, p. 366). In contrast, 'social exclusion' is defined as "being excluded, alone, or isolated" whether or not there are "explicit declarations of dislike" (Williams, 2007, p. 429). It can be non-behavioural and often occurs without explanation; due to its ambiguity, it might go unnoticed by the target of ostracism (Williams, 2001). Therefore, as Leary (2005) points out, it is essential to differentiate between exclusion and rejection, as not all incidents of social exclusion entail rejection. As will be elaborated upon further, Leary (2005) contends that if the individual experiencing exclusion does not perceive a diminished relational value, they may not feel a sense of rejection. Thus, the term 'exclusion' encompasses a broader range of negative interpersonal events, regardless of whether they result in a sense of rejection.

In educational studies, the conceptualisation of social exclusion has seen the emergence of two distinct approaches over the years (Ladd & Kochenderfer-Ladd, 2016). Research methodologies have utilised either *sociometric* or *behavioural* indices of exclusion to conceptualise, measure, and investigate social exclusion (Ladd & Kochenderfer-Ladd, 2016). The *sociometric tradition* conceptualises social exclusion as the result of being 'least liked' within the peer group, defined by intra-group consensual sentiments (e.g., like versus dislike) (Ladd & Kochenderfer-Ladd, 2016). Conversely, the *behavioural exclusion tradition* focuses on how peers behave toward individual group members, evaluating social exclusion based on whether peers actively or passively exercise exclusionary behaviours (Ladd & Kochenderfer-Ladd, 2016). The sociometric construct has notably dominated research on children's social exclusion of peers in school environments (Ladd & Kochenderfer-Ladd, 2016). Some studies have characterised social exclusion solely through sociometric measures (e.g., Ladd et al., 2008; Ladd et al., 1997; Parker & Asher, 1993), while others have integrated both traditions by assessing peer sentiments alongside overt exclusionary behaviours (e.g., Buhs & Ladd, 2001; Buhs et al., 2006; Ladd, 2006). As discussed in Chapter 1, social exclusion within educational settings is increasingly recognised as a form of relational (OECD, 2019) or social bullying (AIHW, 2020), which can be either overt or covert (Cross et al., 2009).

The aforementioned definitions are predicated upon either observable behaviours (e.g., ignoring or denying participation) or the measurable intentions and sentiments (e.g., the extent of disliking as assessed by sociometric analysis) of the *exclusionary agent*. Additionally, existing studies on victims' experiences tend to assume that excluded parties are all capable of identifying exclusion. However, children's ability to identify exclusion varies, and they become more perceptible as they grow older (Hwang & Markson, 2020), although their primitive preference for prosocial behaviours is already observable from infancy (Hamlin, 2015). As outlined in the definition of social rejection above, whether the excluded party will experience any harm partly depends on whether they perceive "their *relational value* is lower than they desire" (Leary, 2005, p. 47). Consequently, dominant conceptualisations in education tend to neglect the processes entailed in excluded agents' anticipation, desire, and subsequent experiences while focusing on exclusionary agents' sentiments and actions. Also, as Hwang and Markson (2020) noted, dominant research methods rely on children's self-reports (e.g., interviews, questionnaires), which may underestimate the extent of real-time feelings of exclusion and emotional pain that are experienced at a subconscious level. For instance, neuroimaging studies have demonstrated that particular regions of the brain, such as the dorsal anterior cingulate cortex (dACC) and the anterior insula, exhibit activation during instances of social exclusion (for a comprehensive review, see Eisenberger, 2013). Importantly, these regions are also implicated in processing physical pain; consequently, some scholars propose that social pain and physical pain may share common neural mechanisms, such as the Pain Overlap Theory (Eisenberger & Lieberman, 2005) and the Social Pain Theory (Macdonald et al., 2005). The various neurophysiological processes underlying social exclusion cannot be adequately assessed using traditional methodologies such as self-reporting, third-party reporting, or observational techniques. As outlined in Section 2.1, from the predictive brain perspective, the human brain can generate various predictions concerning social exclusion based on prior experiences in similar circumstances. The authentic experience of social exclusion as external stimuli or prediction errors merely validates these predictions. Consequently, individuals may experience a wide range of negative effects associated with previous social exclusion before their actual exclusion. This crucial aspect is notably absent in research on social exclusion within psychology and education due to their methodological limitations, which will be elaborated on in greater detail in Section 2.3 and Chapter 3.

In this thesis, while focusing on peer social exclusion within a school context, the term 'social exclusion' will encompass a broad spectrum of exclusionary events, whether deliberate or unintentional. This expanded definition closely aligns with the present study. As delineated in Section 2.3, our newly proposed conceptual framework of social exclusion posits that the experience of exclusion threatens our fundamental need for belonging. Consequently, our predictive brain interprets this experience as harmful, potentially triggering various adverse neurophysiological responses. Therefore, on a neurophysiological level, individuals may truly 'feel' excluded or rejected, even in the absence of conscious awareness of a diminished relative value. Moreover, the social exclusion experiment task used in the current study, framed with a cover story (refer to Chapter 3), combines components of both 'ostracism' and 'rejection', in which participants will find themselves excluded from a gaming team and will receive feedback indicative of 'rejection'. Consequently, insights derived from psychological research on 'ostracism' and 'rejection' will be pertinent and substantially enhance our understanding of social exclusion within the framework of this study. Additionally, despite discrepancies in definitions of social exclusion, researchers often fail to apply precise terminology (e.g., ostracism, exclusion, rejection) consistently, leading to overlapping findings within social exclusion research. Our broader definition of social exclusion aligns with our conceptual framework and research design and is also capable of incorporating insights from psychological literature regarding 'ostracism' and 'rejection', thereby enhancing our exploration of social exclusion.

2.2.2 Why do we exclude others?

From an evolutionary perspective, forming social groups has been fundamental and advantageous for human survival and reproductive fitness; therefore, establishing and maintaining relationships with others has been an essential endeavour faced by our evolutionary ancestors (Leary & Cottrell, 2013). Throughout evolutionary history, our ancestors developed an inclination to form groups and relationships while simultaneously responding adaptively to threats of social rejection (Eisenberger, 2013; Leary & Cottrell, 2013). In essence, human beings are inherently social creatures who desire inclusion in groups and value cultivating positive relationships with others. However, not all individuals exhibit prosocial values; some may threaten our survival and reproductive success, thus being assessed as poor relational partners and group members (Leary & Cottrell, 2013). Consequently, adaptive mechanisms have emerged to assist in evaluating whether forming a potential relationship harbours opportunities for fitness or entails fitness costs (Leary & Cottrell, 2013). Thus, from an evolutionary standpoint, humans are intrinsically motivated not only to form groups and relationships but also to exclude themselves or others selectively. From this viewpoint, both social exclusion and inclusion possess adaptive significance. However, it is foreseeable that this exclusionary event deprives the excluded from accessing desired relationships, which contravenes their fundamental evolutionary needs.

Social psychologists elucidate various social motives underlying social exclusion, including the need for belonging, understanding, control, self-enhancement, and trust in others (North & Fiske, 2013). Firstly, the motive to belong compels individuals to willingly conform to in-group roles and norms, thereby creating a cohesive entity within the group and inevitably excluding outsiders who do not adhere to the established group norms and rules (North & Fiske, 2013). Group dynamics have long been recognised as a significant factor influencing the social exclusion of children (Killen & Rutland, 2011). Additionally, our motive to belong fosters an inclination to cultivate understanding among one another and achieve mutual agreement (North & Fiske, 2013). This collective understanding enables in-group members to perceive the social world similarly and predict others' behaviour in situations of uncertainty (North & Fiske, 2013).

This view aligns with Barrett's (2018) concept of 'collective intentionality', which denotes the consensus on the existence of a concept among a group of individuals, as discussed in Section 2.1. 2. Conversely, the desire to conform to shared beliefs and understandings within the group may inadvertently promote stereotypes about those outside the group and contribute to the social exclusion of outsiders (North & Fiske, 2013). Extensive research in developmental and social psychology shows that young children demonstrate various biases and prejudices early in their development (Killen & Rutland, 2011). The concept of in-group and out-group categorisation forms from a young age (Heck et al., 2022). Furthermore, a lack of comprehension regarding group or social norms is implicated in experiences of social exclusion across various contexts. For instance, research indicates that understanding group norms among children in middle childhood is associated with their relevant experiences in peer relationships through memberships in social groups (Abrams et al., 2009). Consequently, a new student may encounter risks of social exclusion at their new school due to an inadequate understanding of the group norms in this unfamiliar environment.

Moreover, individuals desire their actions to directly impact their social outcomes, thereby seeking a sense of efficacy and autonomy (North & Fiske, 2013). The motivation for control may facilitate exclusion in two primary ways. Firstly, one group may endeavour to exert control over another; for example, a dominant group seeks to maintain power hierarchies and attempts to govern social groups of lower status (North & Fiske, 2013). For instance, a recent study involving children aged 4 to 8 indicated that children from advantaged groups were more inclined to perceive the group hierarchy as fair and generalisable and deemed it inappropriate to contest (Rizzo et al., 2023). Additionally, these advantaged-group children were more prone to exhibit biased intergroup attitudes and exclude members of disadvantaged groups (Rizzo et al., 2023). Furthermore, as children aged, the advantaged and disadvantaged groups increasingly recognised membership in their own group as hereditary while simultaneously judging the hierarchy as more unjust and expecting its generalisation across various contexts (Rizzo et al., 2023). The motivation for control may be associated with various phenomena related to stereotyping and prejudice, including racism, sexism, and ageism (North & Fiske, 2013). The second form of exclusion related to control is reflected in passive ignorance (North & Fiske, 2013). If individuals believe they do not require anything from the excluded, they may simply disregard them.

Self-enhancement is recognised as the fourth core motive driving individuals to maintain a positive self-perception, sustain a sense of self-worth, and boost their self-esteem (North & Fiske, 2013). Individuals with higher self-esteem typically feel better about themselves and exhibit greater assertiveness (North & Fiske, 2013). However, the pursuit of self-esteem can incur certain costs for both in-group and out-group participants (North & Fiske, 2013). When the pursuit of self-enhancement is threatened within the group, individuals may experience various negative emotions, see a decline in interpersonal relationships with fellow group members, and increasingly shift their focus toward individual interests, thus deviating from collective goals (North & Fiske, 2013). In contrast, when the pursuit of self-enhancement is closely linked to group affiliation, it frequently results in excluding out-group members (North & Fiske, 2013). This core motive may be less applicable to young children, as their self-identity and group identity are still developing.

The fifth and final core social motive is people's need to trust others (North & Fiske, 2013). Trust constitutes a fundamental requirement, essential for establishing intimate relationships and forming bonds within a group. However, individuals tend to prefer trusting members of their in-group while harbouring distrust toward outsiders. This inclination can exacerbate the differentiation between in-groups and out-groups, enhancing the bonds within the in-group and facilitating the social exclusion of out-group members (North & Fiske, 2013). For instance, children exhibit a developing sense of morality early in life, demonstrating notions of fairness as early as two to three years of age (Killen & Rutland, 2011). Concurrently, they may display a degree of distrust toward those perceived as different, as well as tendencies toward selfish behaviours and in-group favouritism (Killen & Rutland, 2011).

In summary, the core motives approach posits that the need for belonging represents the most fundamental goal for human beings (North & Fiske, 2013). With this foundation, humans are further motivated to cultivate a shared understanding of the social world with others (understanding), attain a sense of control over their actions (control), enhance their self-esteem (self-enhancing), and depend on others while navigating their social environments (trusting others) (North & Fiske, 2013). These five motives may contribute to instances of social exclusion under various circumstances. Nevertheless, the fourth core motive, self-enhancement, is less pertinent to young children compared to the other four motives. This specific motive requires a more nuanced understanding of individual and group identity and a heightened proficiency in cognitive abilities.

Leary (2005) presents an alternative perspective by elucidating the rationale behind exclusion from the relational value perspective. He posits that individuals attribute differing levels of value to their relationships with others and social exclusion does not inherently entail rejection unless the excluded individual perceives it lowers a relational value. From this viewpoint, individuals' perceptions of diminished relational value are a crucial determinant of whether they feel rejected (Leary, 2005). He argues that all adverse interpersonal occurrences that involve interpersonal rejection entail situations wherein one individual does not appreciate his or her relationship with another person (Leary, 2005). All phenomena associated with interpersonal rejection—such as ostracism, childhood peer rejection, exclusion, bullying, neglect, betrayal, and humiliation, among others—can diminish individual's perceived relational value (Richman & Leary, 2009). Leary (2001) contends that conceptualising rejection through the lens of relational evaluation enables us to operationalise "the subjective reactions of both the rejector (low relational evaluation) and the rejected (low perceived relational evaluation)" (p.17). However, this operationalisation relies on an individual's conscious and effortful evaluation of shifting relational values. It fails to account for other potential factors and outcomes associated with rejection, particularly those related to neurobiological functions, as one cannot assert that the rejected individual does not experience feelings of rejection or exclusion at a neurobiological level, even if they cannot explicitly describe a diminished relational value. Notably, his theory holds less applicability for young children who are still in the process of developing their linguistic, social, and emotional capabilities. The rejector may simply have an intuitive preference for or aversion to engaging with another individual, while the rejected individual continues to feel the pain of exclusion instinctively, without being able to report their assessment of relational value, as suggested by his theory.

Killen and Rutland (2011) adopt an integrative social-cognitive developmental perspective on social exclusion. They assert that a comprehensive understanding of social exclusion and inclusion during childhood necessitates considering the development of moral reasoning, the ability to consider social categorisation—identifying social categories that organise individuals into distinct groups—and prejudice, which is understood as the negative evaluation of individuals based on their affiliation with a specific social group (Killen & Rutland, 2011). For instance, concerning moral reasoning, Killen and Rutland (2011) claim that as children transition into adolescence, they develop an increased ability to contemplate multiple issues and perspectives simultaneously when faced with moral dilemmas. This means individuals cultivate the capacity to assess a vast array of contextual information—such as individual intentionality, motivations, emotions, and the ability to comprehend others' mental states; group dynamics encompassing power, status, and hierarchies; and societal elements including traditions, customs, and rituals—while forming moral judgments (Killen & Rutland, 2011).

Regarding social categories, children begin to recognise distinctive characteristics of individuals both within their own social group and those from other groups from infancy. They use this understanding to categorise individuals into social groups (Killen & Rutland, 2011). Empirical studies suggest that once infants identify these social categories, they usually exhibit a preference for members of their own group over those from different groups (Killen & Rutland, 2011). As children become more aware of social categories, their affiliations with social groups attain significance comparable to their relationships with parents and family (Killen & Rutland, 2011). These group identities rapidly assimilate into a child's life, shaping their thoughts, behaviours, and decision-making processes (Killen & Rutland, 2011). For example, as social identification increases during middle childhood, children tend to differentiate among their peers based more on group membership rather than moral considerations (Abrams et al., 2008). These observations clarify why, despite their strong sense of morality, children still display pronounced intergroup bias and socially exclude peers during middle childhood (Abrams et al., 2008).

Moreover, these authors identify three aspects of group dynamics that children contemplate when making decisions regarding exclusion: their expectations concerning group identity, group-specific norms, and how children perceive these norms in relation to various domains, including moral and conventional criteria (Killen & Rutland, 2011). On one hand, groups provide children with a sense of belonging and support. For example, when children from socially excluded groups establish a positive affiliation with their cohort and receive support from their peers and parents, their experiences of social exclusion may be mitigated (Killen & Rutland, 2011). Therefore, there exist contexts in which membership in an excluded group can empower children and adolescents to address social inequalities and actively combat social exclusion (Killen & Rutland, 2011). Conversely, groups can also engender pronounced ingroup/outgroup distinctions, which may lead to violence and harm—a phenomenon sometimes associated with gang participation (Killen & Rutland, 2011). Furthermore, research indicates that when the peer group of primary school students establishes an exclusive norm and holds them accountable to their peers or teachers, the effectiveness of the inclusive school norm declines (McGuire et al., 2015).

In addition to outgroup exclusion—characterised by the exclusion of members from external groups and the demonstration of bias against children from those groups—intragroup exclusion, which entails the exclusion of individuals within one's own group along with the display of ingroup bias, represents another form of social exclusion among children (Killen & Rutland, 2011). One explanation for intragroup exclusion is the violation of established group norms (Killen & Rutland, 2011). While it acknowledges the developmental disparities between adolescents and younger children, this approach places considerable emphasis on cognitive abilities in the context of social exclusion. This perspective is problematic as it presumes that both adolescents and younger children are rational entities capable of 'reasoning' devoid of emotion. Such an approach exemplifies a conventional dualism between 'emotion' and 'cognition'.

Similarly, Mulvey (2016) contends that the factors contributing to the social exclusion of children and adolescents within group contexts derive from a complex interplay of individual and group factors, such as their social-cognitive competencies, contextual influences, emotion evaluations, and the tensions between conflicting moral and group-oriented norms. In group-based social exclusion, individuals are obligated to navigate the tension between ethical principles—most notably harm prevention and the pursuit of fair and equitable treatment—and their loyalty to the group (Mulvey, 2016). Children and adolescents confront these intricate scenarios by meticulously evaluating contextual factors, reflecting on the emotional experiences of themselves, the excluders, and the excluded while leveraging their social-cognitive abilities (Mulvey, 2016). For example, when a child harbours negative sentiments toward a group member, they are predisposed to rationalise the exclusion of that individual as justifiable. As children mature, they cultivate a more advanced and nuanced reasoning capacity regarding social exclusion in varying contexts (Mulvey, 2016). Despite recognising the importance of emotional evaluation in relation to the factors contributing to social exclusion, akin to the perspectives presented by Killen and Rutland (2011), Mulvey (2016) continues to emphasise children's cognitive capabilities that detach emotion as a means of explaining instances of social exclusion among children.

The preceding discussion offers valuable insights into the explanations addressing why individuals exclude others from various theoretical perspectives. Most of these perspectives involve some form of cognitive evaluation or appraisal, which ultimately leads to the outcomes or consequences associated with social exclusion. Essentially, akin to the traditional emotion theories examined in Section 2.1.1, these explanations predominantly adopt a simplistic linear causation in elucidating the rationale behind social exclusion. They primarily emphasise 'cognition', often neglecting the significant role of emotion in contributing to this phenomenon.

This illustrates the dualistic perception of the mind and body, a perspective commonly found within Western rationalist or cognitivist paradigms.

2.2.3 Victims' experiences of social exclusion

Experiencing rejection or exclusion by others can have varying levels of impact on individuals, both immediately and over an extended period. Some psychological theories posit a linear perspective on such influences, suggesting that the victim's response to social exclusion unfolds following a temporal progression. An illustrative example is Williams's Temporal Model of Ostracism (2001), which asserts that ostracism affects individuals over three distinct phases: immediate, short-term, and long-term reactions to ostracism. This model posits that individuals subjected to ostracism initially experience automatic *reflexive* responses, such as feelings of hurt, anger, a bad mood, or physiological arousal (Williams, 2001). This reflexive stage demonstrates the immediate effects of ostracism, which are instinctual in nature and resistant to moderation by individual differences or contextual variables (Williams, 2007). The premise behind this description is that people are only 'reactive'. This description of 'reflexive' responses does not consider the brain's predictive nature and its subsequent evaluation of 'good' or 'bad,' manifesting through homeostasis feeling. Following this initial phase, a *reflective* stage ensues, wherein the ostracised individual consciously deliberates on their experience and endeavours to restore any lost or threatened needs engendered by the act of ostracism (Williams, 2001). The reflexive and reflective stages correspond to immediate and short-term reactions to ostracism, respectively. Prolonged exposure to ostracism leads individuals to enter a third phase—namely, the *resignation* stage (Wesselmann & Williams, 2013). In this phase, individuals may perceive their efforts to restore lost needs or terminate ostracism as futile (Wesselmann & Williams, 2013), leading them to accept their loss and experience helplessness and despair. Consequently, these victims of sustained and continuous ostracism may endure significant psychological and health-related challenges (Wesselmann & Williams, 2013; Williams, 2001). These three phases resemble the 'sense-think-act' model inherent in traditional cognitivism, assuming that a victim is a rational decision-maker in their own social relationships. While acknowledging the harmful impacts of exclusion on victims' well-being, this model is rather problematic in explaining young children, whose cognitive and emotional regulation capabilities are still developing.

Similarly, Richman and Leary (2009) posit that exclusion or rejection significantly affects victims over varying temporal durations. Firstly, it precipitates immediate negative emotional responses, most notably hurt feelings and lowered self-esteem (Richman & Leary, 2009). They assert that these immediate responses are universal among individuals experiencing rejection. In other words, rejected individuals often encounter feelings of hurt and diminished self-esteem, even when the rejection does not undergo cognitive evaluation or processing. This perspective aligns closely with basic emotions theories (e.g., Izard, 2007; Panksepp, 1998), where universal emotions are evoked by certain types of stimuli. Nonetheless, they argue that how individuals respond to rejection following the immediate and automatic phase varies based on numerous factors. A key factor is the motivations underlying individuals' responses following instances of rejection. According to Richman and Leary (2009), three distinct motives concurrently shape individuals' responses to rejection: seeking acceptance, harming others, or withdrawing socially. Additionally, the tendency of individuals who experience rejection to respond in a prosocial, antisocial, or avoidant manner is moderated by six categories of factors: the perception of unfairness or injustice, the value assigned to the damaged relationship, the feasibility of alternative relationships, the chronicity and pervasiveness of rejection, the perceived costs associated with the rejection, and expectations regarding relational repair (Richman & Leary, 2009). For example, if individuals perceive that they have been treated unjustly, they are more likely to engage in antisocial behaviour (See Figure 2.2.3.1). This presents a highly debatable framework of causal links, where experienced educators might easily identify examples that do not conform to the proposed causal links. If a child perceives that others are treating him unfairly during a game, he may avoid this group of peers or report the unfair behaviour to teachers or other authority figures (Kim et al., 2021). However, such social behaviours, frequently observed in children, are not accounted for by this model.

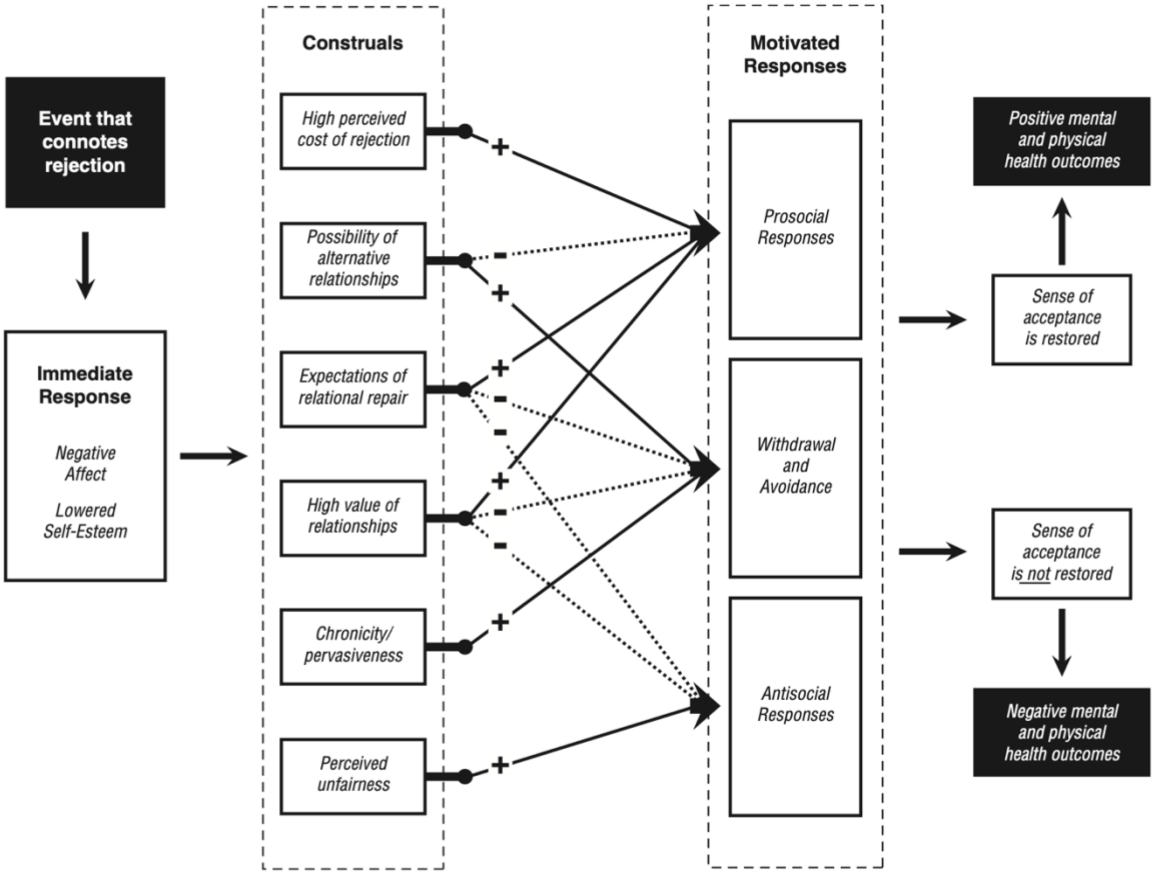


Figure 2.2.3.1 Multi-Motive Model of reactions to interpersonal rejection experiences

(Richman & Leary, 2009, p. 369)

In conclusion, social exclusion represents a complex phenomenon that profoundly influences the emotional, psychological, and physiological well-being of those affected. Individuals who experience such exclusion often encounter significant distress, profound feelings of isolation, and negative self-perception, which may result in harmful changes across various aspects of their lives. The intensity and nature of these experiences are shaped by individual characteristics, the specific context of exclusion, and the duration of its occurrence. Insights gained from the experiences of individuals who have faced social exclusion, as illustrated in the preceding models, considerably enhance our understanding of these matters and provide essential information relevant to addressing Research Question 1 concerning the victim's emotional experiences. However, it is imperative to acknowledge that these explanations exhibit considerable limitations. Firstly, they presume that victims of social exclusion are passive and reactive participants awaiting external stimuli without considering the brain's predictive capabilities and subsequent evaluation of 'good' or 'bad', which manifests through homeostasis feelings. Secondly, they frequently propose overly simplistic linear causal relationships among various factors, failing to adequately clarify the complexities inherent in social exclusion among young children. Lastly, their 'sense-think-act' framework for elucidating the victim's experiences of social exclusion reflects the dominant dualism characteristic of traditional cognitivism, suggesting that a victim operates as a rational decision-maker capable of making choices devoid of emotional influence. This methodological approach presents significant challenges when applied to young children, whose cognitive and emotional regulatory capacities are still developing.

2.2.4 The role of context: Need to adopt the 'socially-embedded brain' perspective

Apart from being posited on the linear perspective of old cognitivism, Williams' Temporal Model of Ostracism (2001) and Richman and Leary's (2009) Multi-Motive Model do not adequately acknowledge the critical importance of contextual factors. In contrast to these two approaches, the Transactional Model for Adaptation to Peer Rejection focuses on person-context transactions when examining children's subjective reactions to peer rejection

(Sandstrom & Zakriski, 2004). The Transactional Model for Adaptation to Peer Rejection aligns with Richman and Leary's (2009) Multi-Motive Model of responses to rejection, acknowledging the pivotal function of how the victim appraises the exclusion experience in shaping their subjective experience (Sandstrom & Zakriski, 2004). Furthermore, it emphasises the dynamic interplay between experiences of rejection, children's appraisals, and their collective influence on children's subjective experiences, as noted by Sandstrom and Zakriski (2004). Additionally, it highlights the broader contexts in which exclusion episodes occur (Sandstrom & Zakriski, 2004). According to this framework, a rejected child's appraisal of a rejection event may vary based on the child's social goals and concerns, general expectations, perceptions of the social environment, and the characteristics of surrounding social occurrences, among other factors (Sandstrom & Zakriski, 2004). By emphasising appraisal, this perspective resembles the previously mentioned models in highlighting a contextually detached and serial-processing cognitive framework.

Regarding context, Sandstrom and Zakriski (2004) make an important distinction between sociometric rejection and children's actual rejection experienced in their daily lives. When a child's sociometric score is significantly below the group average, that child is classified as sociometrically rejected (Asher et al., 2001). The sociometric score is derived from a combined analysis of positive and negative sociometric nominations, wherein children indicate the names of their most and least preferred peers (Asher et al., 2001). Sociometrically rejected individuals are more vulnerable and may endure a diverse array of rejection experiences, which range from explicit rejection (e.g., overt expressions of disfavour) and overt victimisation (e.g., physical harm or verbal abuse) to tolerance (e.g., selecting a disliked child for a mathematics project due to their proficiency in the subject) and even unintentional reward (e.g., acquiescing to a bully without expressing disapproval) (Sandstrom & Zakriski, 2004). However, sociometric rejection, “being only a group summary of private affective evaluations” (Sandstrom & Zakriski, 2004, p.113), is very limited in explaining a child’s well-being. There is no such an ‘average victim’ who is victimised regardless of contexts, relational dynamics, and situational factors. The incidents of exclusion and victimisation rather emerge from the intricate dynamics of social contexts. Additionally, the extent of harm or negative experiences perceived by the victim is constructed with inputs from multiple social and contextual factors.

In conclusion, it is essential to analyse the contextual factors when evaluating children’s subjective experiences of social exclusion. These contexts comprise not only the immediate environment in which the incident of exclusion occurs but also the broader circumstances surrounding any specific episode of social rejection. Such contextual variations significantly influence the subjective experiences of an excluded child (Sandstrom & Zakriski, 2004). Nevertheless, numerous traditional models inadequately incorporate this dimension within their frameworks. These limitations necessitate the adoption of the socially embedded brain perspective, which will be elaborated upon in Section 2.3, where a novel framework for social exclusion will be introduced. Moreover, this study embraces the importance of contexts by examining how children’s sense of belonging to their own school correlates with their anticipation and responses towards inclusion or exclusion by unfamiliar peers. While one’s sense of belonging is formed over an extended period while being embedded within a familiar school environment, does that sense act as a protective factor when embedded in a new situation where unfamiliar peers exclude the child? This question will be answered by the experimental component of this study while firmly embracing the ‘socially embedded brain’ view.

2.2.5 Social exclusion at schools, students' well-being and sense of belongingness

As previously noted, social exclusion represents a form of relational (OECD, 2019) or social bullying (AIHW, 2020) that can manifest both overtly and covertly (Cross et al., 2009). Reports published by the OECD in 2017 and 2019 indicate that bullying remains a prevalent concern within educational institutions globally, with covert bullying exhibiting a concerning increase in both prevalence and insidious nature, as noted by Cross et al. in 2009. Specifically, as discussed in Chapter 1, a greater proportion of students in Australia report experiencing bullying monthly compared to the global average, as highlighted by the OECD in 2019, with approximately one in six Australian children reporting instances of covert bullying (Cross et al., 2009). Furthermore, a higher percentage of these students indicate experiencing social exclusion as a subtype of covert bullying relative to other forms of bullying (Cross et al., 2009). Recent data reveals that 32.2% of Australian students in grades seven through eleven have reported experiencing relational or social bullying (Thomas et al., 2016). Although updated statistics on covert or relational bullying among younger Australian students are currently unavailable, there is a clear trend in overall bullying statistics reported, showing a notable increase from 27% in 2009 (Cross et al., 2009) to 35% in 2023 (Hillman et al., 2023). This trend indicates a potential increase in relational bullying within this demographic.

Social exclusion experienced by schoolchildren not only brings personal distress but may alter their sense of belonging to their school, posing existential threats to victims. A sense of belongingness "is related to the basic and universal human quest for meaning or meaningfulness in life" (Kim & Sankey, 2022, p.294). Conversely, social exclusion violates our fundamental need for belonging. In the upcoming session, we will initially introduce Yuval-Davis's (2006) conceptual framework concerning the notion of belonging and examine its relevance and application within the field of education, particularly focusing on the intricate interconnections between belonging and social exclusion. Following this introduction, we will present empirical findings from the literature that demonstrate the beneficial effects of school belonging on students' overall well-being, especially highlighting the mediating role of school belonging in mitigating some of the negative effects associated with social exclusion.

Social exclusion and sense of belongingness

Yuval-Davis (2006) contends that the concept of belonging represents a complex and dynamic process constructed through three interrelated analytical dimensions: social locations, identifications and emotional attachments, as well as ethical and political values. Social location refers to an individual's affiliation with a specific gender, race, class, or nationality, and it encompasses a range of complexities (Yuval-Davis, 2006). Within an educational institution, our students hail from diverse cultural, linguistic, and ethical backgrounds. From an early age, children become increasingly aware of the differences that exist among various groups of people. The second dimension, identifications and emotional attachments, includes the narratives people tell themselves and others about who they are; these stories often relate, directly or indirectly, to self and /or others' perceptions of being a member of such a specific group. Yuval-Davis (2006) further emphasises that constructions of belonging extend beyond mere 'cognitive stories' to include emotional investments and an intrinsic desire for connections. From this perspective, students' self-identity and their engagement with others emerge as crucial factors influencing their sense of belonging within the school environment.

Ultimately, she posits that belonging transcends social locations and the formation of individual and collective identities and attachments, also involving the valuation and perception of these elements (Yuval-Davis, 2006). In examining the third dimension, she discusses the politics of belonging and the formation of boundaries. Specifically, she articulates, "The boundaries that the politics of belonging is concerned with are the boundaries of the political community of belonging, the boundaries that separate the world population into 'us' and 'them'" (Yuval-Davis, 2006, p.204). This notion is particularly relevant to current discussions surrounding social exclusion and belonging. As previously indicated, the dichotomy between 'us' and 'others' constitutes a critical factor in the landscape of social exclusion, often established from a young age (refer to Heck et al., 2022 for a comprehensive review).

Yuval-Davis (2006) presents a conceptual framework that outlines critical aspects of belonging and its political dynamics. Although her theory of belonging is not expressly formulated for educational contexts, it has significant implications for the educational sector. Her conceptualisation shares numerous similarities with the definition of school belonging in the field of education. In this domain, a diverse array of terminologies elucidates the concept of school belonging, including, but not limited to, the following: school bonding, school connectedness, school attachment, school identification, belongingness, sense of community, school engagement, and school involvement (Štremfel et al., 2024). Despite the variations in terminology, the fundamental themes—students' emotional connections with others, their sense of having a place within the school, and their feelings of inclusion—remain consistent across these definitions (Štremfel et al., 2024). Of particular significance, Yuval-Davis's discourse on the politics of belonging accentuates the interconnection between social exclusion and the concept of belonging. Specifically, her assertion that the politics of belonging involves establishing and maintaining boundaries demarcating 'us' from 'them' represents an essential dimension of social exclusion. In this context, the discourse surrounding belonging must invariably engage with the concepts of social inclusion and exclusion. Furthermore, the second dimension—namely, identifications and emotional attachments—highlights the importance of interpersonal relationships in fostering a sense of belonging.

Within an educational environment, these crucial relationships involve interactions among peers and between students and educators. A recent study examined the perspectives of children aged 4 to 8 years regarding the factors they deem essential for nurturing a sense of belonging within their educational settings across five nations (Einarsdottir et al., 2022). The findings indicated that, from the children's perspective, belonging is intricately linked to friendships, the presence of caring and trustworthy adults, and being accepted as members of their educational communities (Einarsdottir et al., 2022). Importantly, the children articulated both inclusive and exclusive processes while emphasising the importance of community membership (Einarsdottir et al., 2022). From the children's viewpoint, their sense of belonging within their educational environment is founded on the acceptance of others and their own acceptance- elements that are profoundly valued and closely related to inclusion and participation within a community (Einarsdottir et al., 2022). Moreover, the narratives conveyed by the children concerning their sense of belonging in educational contexts frequently reflect tensions surrounding inclusion versus exclusion, empathetic versus authoritative educators, identification with specific ethnic or gender groups versus integration within the broader community, and the reconciliation of institutional regulations with children's autonomy in decision-making processes (Einarsdottir et al., 2022). These findings further emphasise the intricate relationship between social exclusion and a sense of belonging within educational settings, as well as the complexities inherent in young children's social lives.

A student's sense of belonging in school reflects how accepted, respected, included, and supported they feel within their schools (Goodenow & Grady,1993). Social exclusion significantly compromises students' school belongingness. For instance, OECD reports indicate that "students in schools with a high prevalence of bullying were also more likely to report a weaker sense of belonging at school" (OECD, 2019, p. 46) and "on average across OECD countries, approximately 42% of students who are frequently bullied – but only 15% of students who are not frequently bullied – reported feeling like an outsider at school" (OECD, 2017, p. 4). A similar observation was made in Australia; the ACBPS report highlights that social exclusion correlates with diminished levels of connectedness to the school (Cross et al., 2009). Additionally, besides undermining students' sense of belonging, social exclusion has numerous adverse effects on their well-being. For instance, peer exclusion, a deficit in friendships, and poor friendship quality are positively correlated with feelings of loneliness and social dissatisfaction among primary students (Ladd et al., 1997; Parker & Asher, 1993). In contrast, social inclusion strongly predicts students' life satisfaction (Arslan et al., 2020). Moreover, children who experience exclusion frequently encounter feelings of sadness and loneliness, suffer from social anxiety and depression, and exhibit diminished self-esteem and a poor self-concept (Sandstrom & Zakriski, 2004). Similarly, the Australian report on covert bullying indicates that victims often endure a range of negative emotions, including loneliness, fear, anger, hurt, annoyance, embarrassment, stress, helplessness, and overall dissatisfaction with their educational experiences (Cross et al., 2009). Moreover, students who experience social exclusion exhibit substantially heightened levels of psychological distress compared to their peers who endure verbal bullying, rumour spreading, and physical bullying (Thomas et al., 2016). Furthermore, social exclusion serves as a predictor for students' internalising and externalising issues (Arslan et al., 2020).

On the contrary, school belongingness exerts a positive influence on students' well-being and their academic performance and success (OECD, 2019; Štremfel et al., 2024). For instance, research indicates that students' sense of belonging at school partially mediates the effects of bullying victimisation and bullying climate on academic performance (Huang, 2022). Furthermore, a recent study reveals that school belonging mediates the relationship between socioemotional well-being and loneliness among primary students (Palikara et al., 2021). In addition, a recent investigation into the relationship between students' perceptions of school climate and negative emotions concludes that a positive school climate, both directly and indirectly, mitigates negative emotions, with school belonging and social avoidance serving as significant mediators (Chen et al., 2025). Specifically, this study indicates that perceived school climate fosters a sense of belonging, which subsequently alleviates social avoidance and distress, ultimately leading to a reduction in negative emotions (Chen et al., 2025). Among the factors analysed, peer support exhibits the most substantial indirect effect (97.50%), followed by teacher support (82.05%) (Chen et al., 2025). The authors posit that these findings illuminate the critical role of peer relationships in fostering school belonging and alleviating distress (Chen et al., 2025). The significance of peer relationships and their connection to school belonging is further underscored in another recent study. Forsberg (2023) found that while the formation of friendships among children evolves over time, the fundamental need to belong remains a constant, regardless of the developmental trajectories of these friendships within the school context (Forsberg, 2023). Most importantly, this intrinsic need to belong emphasises a persistent apprehension regarding exclusion associated with the school experience (Forsberg, 2023). Moreover, students with a stronger sense of belonging are likely to attain higher scores in reading assessments, demonstrate elevated levels of cooperation with peers, and exhibit an increased likelihood of pursuing a university degree (OECD, 2019).

The impact of social exclusion on students' academic performance

As previously articulated, social exclusion and rejection adversely affect students' psychological, physical, and social well-being. Furthermore, social exclusion negatively impacts academic performance through various mechanisms. Firstly, children experiencing social exclusion are more prone to marginalisation in academic activities within the classroom (Ladd et al., 1997) and exhibit a significant decline in participation (Buhs et al., 2006; Cross et al., 2009; Ladd et al., 2008; Ladd et al., 1997). This withdrawal from classroom activities results in diminished learning opportunities and, consequently, lower academic performance (Buhs et al., 2006). Research suggests that chronic peer maltreatment in primary school, characterised by sustained peer exclusion and abuse, serves as a predictor of future disengagement from school (Buhs et al., 2006). Additionally, the correlation between peer rejection in kindergarten and academic performance in middle school is significantly influenced by children's experiences of ongoing peer exclusion and decreasing classroom participation (Buhs et al., 2006). Secondly, social exclusion is associated with increased school avoidance (Buhs & Ladd, 2001; Buhs et al., 2006; Ladd, 1990; OECD, 2017) and negative perceptions of the school environment (Buhs & Ladd, 2001; Ladd, 1990). This, in turn, further diminishes academic engagement and achievement. Thirdly, as previously discussed, social exclusion exerts a broad range of negative impacts on students' mental health and well-being, which subsequently affects academic performance. In summary, a substantial body of evidence within the education literature indicates a correlation between social exclusion and a decline in academic performance (Buhs & Ladd, 2001; Buhs et al., 2006; Cross et al., 2009; Ladd, 1990; Ladd et al., 1997). Moreover, peers play a significant role in influencing students' academic learning (Ladd & Kochenderfer-Ladd, 2016). Recent data from Year 4 Australian students clearly demonstrates a correlation between a high sense of belonging and significantly higher reading performance; in contrast, there was a negative relationship between reading achievement scores and bullying experiences (Hillman et al., 2023).

The influence of peers on student learning within the classroom context has gained increasingly significant importance in light of ongoing educational transformations. A prevalent global trend in education involves redesigning learning environments and shifting from traditional, formal settings to more adaptable and future-oriented learning spaces (Freeman et al., 2017). This trend is also observable in Australia, where flexible learning environments are incorporated into numerous newly constructed or under-construction public school facilities in New South Wales. In these flexible learning contexts, students are expected to assume greater responsibility for their educational journeys and engage more actively with their peers through small-group collaborations and projects. Moreover, conventional teacher-centred pedagogical methods—where educators were the primary sources of knowledge—are undergoing a notable transition (Freeman et al., 2017). Educators increasingly depend on peer interactions to support student learning and achievement within the classroom (Ladd & Kochenderfer-Ladd, 2016). Consequently, students encounter a progressively challenging environment that necessitates enhanced collaboration with peers, with diminished teacher direct intervention. This shift elevates the likelihood of confronting social and emotional challenges in peer relationships. Among the numerous potential challenges that students may confront, peer social exclusion emerges as a particularly pressing concern (Ladd et al., 1997). Regrettably, fewer students who experience a higher incidence of bullying report feeling encouraged to cooperate with their peers (OECD, 2019). Given that chronic social exclusion has been negatively associated with classroom participation, school engagement, and academic performance, the issue of peer social exclusion presents a particularly pressing concern within educational institutions.

In conclusion, social exclusion, often regarded as a subtle form of bullying, is a pervasive issue in educational settings that leads to numerous detrimental psychological, physical, and social consequences for students. This phenomenon is not merely an unfortunate aspect of school life; it significantly hinders students' learning and academic achievement. The concepts of belonging and social exclusion are deeply intertwined, creating a complex web that significantly influences students' experiences. Fostering a sense of belonging within the school serves as a vital protective factor against social exclusion, underscoring the importance of creating inclusive environments that promote mental health and educational success. By recognising and addressing the repercussions of social exclusion, we can enhance students' sense of belonging, thereby improving their well-being and nurturing a more supportive educational atmosphere.

2.2.6 Critical appraisals of educational and developmental research on social exclusion

The literature review presented in the preceding sections has shed significant light on a range of crucial inquiries. These include the complex issues surrounding definitions, the underlying motivations, the experiences of victims, the contextual factors influencing social exclusion, and its profound impact on students' sense of belonging, well-being, and academic performance. This rich body of literature, drawn from both psychology and education, serves as a beacon of knowledge, fostering a deeper understanding of the intricate complexities surrounding social exclusion. These insights are vital not only for enhancing our comprehension of this phenomenon but also for guiding future research and interventions. Nevertheless, they also illuminate several limitations that warrant further investigation.

Firstly, the prevailing conceptualisation of social exclusion in education primarily focuses on observable behaviours or measurable intentions and sentiments of the exclusionary agent.

However, this focus often overlooks the processes related to the anticipation, desire, and subsequent experiences of excluded individuals. Additionally, commonly used research methods depend heavily on children's self-reports; however, young children may be particularly susceptible to various biases in self-reporting as their social, emotional and cognitive capabilities are still developing. Moreover, due to methodological constraints, research into social exclusion within psychology and education primarily focuses on universal constructs such as appraisal, emotional distress, aggression, and withdrawal. Few studies have effectively clarified the real-time neurobiological mechanisms that underpin social exclusion and its emotional dynamics. This underrepresentation of neurobiological mechanisms in current research highlights the urgent need for more rigorous research methodologies to facilitate a deeper understanding of this issue and to steer future research in a more targeted direction.

Secondly, conventional theories often employ a simple linear causation model, typically advocating a 'sense-think-act' framework in which events occur sequentially: an adverse interpersonal incident incites immediate and automatic responses, subsequently followed by more intentional reactions. These theories overlook a crucial aspect—the brain's predictive capabilities. They assume that victims of social exclusion are passive and reactive participants who await external stimuli to elicit responses. This oversight disregards the brain's inherent predictive nature and subsequent valuation of 'good' or 'bad,' manifesting through homeostasis feeling. Furthermore, these theories fail to acknowledge the essential roles of emotion and the body in victims' experiences of social exclusion, presuming instead that victims act as rational decision-makers in their social relationships. This situation becomes especially concerning when analysing social exclusion among young children, whose brains—particularly the frontal lobes—and cognitive abilities are still developing.

Lastly, numerous conventional theories and research concerning social exclusion in psychology and education predominantly concentrate on particular facets of this intricate phenomenon. Nevertheless, these approaches frequently overlook the comprehensive complexity of social exclusion, characterised by complex interactions among various individual and contextual factors. An exclusive emphasis on one or a limited number of aspects of this phenomenon is inadequate for a thorough understanding. Consequently, there is a pressing necessity for a more holistic approach to studying social exclusion.

The limitations of conventional studies of social exclusion, therefore, necessitate the formulation of a new and more comprehensive framework. This framework must thoroughly consider the factors operating at multiple levels and their dynamic interactions that contribute to the emergence of new behaviours and developmental patterns. In the subsequent section, the proposed framework will be presented, which integrates the embodied, socially, and culturally embedded predictive brain perspective in the examination of social exclusion.

2.3 Synthesis of theories and formulations of the conceptual framework of social exclusion in education

As previously stated, the central premise of this thesis is that children's development is an 'emergent' and 'self-organising' (not pre-programmed) process, a product of neurobiological changes occurring within the embodied and predictive brain, which is embedded within multiple shifting social and cultural contexts (Kim & Sankey, 2022). Consequently, emotions are 'emergent' and 'constructed' from dynamic processes occurring interoceptively within the embodied, predictive brain and also as it interacts with and responds to multiple socio-cultural contexts in which it is embedded. The present section will describe how these contemporary views of 'human development' and 'emotion' have guided the conception of the study design.

Developmental scientists have long acknowledged that neurobiological and sociocultural factors in human development 'co-act' and mutually influence one another (Overton, 2006; Gottlieb & Halpern, 2008). Immordino-Yang and Gotlieb's (2017) conceptions on emotional development align with this notion, as they propose in their 'biopsychosocial framework for affective processing' (See Figure 2.3.1.1), "neurobiological and sociocultural development are *co-dependent*; neither can exist without the other, and each influences and organises the other over time" (p. 345). This framework aligns with the long-standing 'relational' view within the science of human development (e.g., Overton, 2006; Gotlieb & Halpern, 2008) while incorporating the 'constructive' nature of emotions and emotional development. It is, however, somewhat limited in that its account of emotional development does not incorporate the brain's 'predictive' processing, nor does it offer nuanced details regarding 'real-time' and 'here-and-now' affective processes that emerge as children engage with social environments (e.g., peers, classroom routines). In order to accommodate these ideas, the framework requires the incorporation of 'feedback loops' (Kim & Sankey, 2022, p. 242) as a key process.

Accordingly, this section begins with a critical examination of Immordino-Yang and Gotlieb's (2017) biopsychosocial framework of affective processing, with the aim of offering a revised and enriched framework that is equipped with more nuanced descriptions of 'here-and-now' affective processes as experienced by individuals situated in given contexts. This proposed framework is enriched by incorporating key ideas from the 'predictive brain' theory, which explains how the brain's anticipatory processes channel the subsequent affective processes. We anticipate this framework will offer valuable insight into the experience of 'social exclusion', where the history of past experiences shapes the victim's anticipation when facing a subsequent exclusion. The enriched framework will inform and be incorporated into the design of the experimental procedure and data collection plan of the current study, as detailed in Chapter 3.

2.3.1 Critical review of the biopsychosocial framework for affective processing

As illustrated in Figure 2.3.1.1 below, the biopsychosocial framework for affective processing comprises four dynamically interacting levels: "bodily functioning, embodied brain, social mind, and culturally situated meaning-making" (Immordino-Yang & Gotlieb, 2017, p.360). This model has numerous strengths. Firstly, it highlights the essential role of the body within the overall process by positioning it at the foundation of the spiral. Bodily functions, which reflect the physiobiological aspect of human existence, are regulated according to social-cognitive appraisals of diverse situations, and these regulations are guided and mapped by the embodied brain (Immordino-Yang & Gotlieb, 2017). Secondly, it acknowledges that the embodied brain is situated within a broader social and cultural context by emphasising the dynamic interactions among the four levels of this framework. The embodied brain not only maps and regulates bodily functions but also "constrain and support the social functions of the mind, and ultimately the adoption of social beliefs, norms, and roles" (Immordino-Yang & Gotlieb, 2017, p.360).

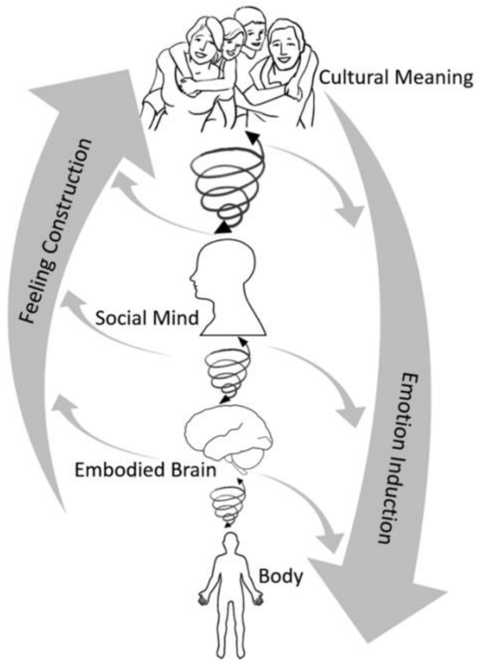


Figure 2.3.1.1 A biopsychosocial framework for affective processing

Furthermore, the third level, designated as the social mind, "constrains and supports acculturation by interpreting patterns of social interaction, social-emotional feelings, beliefs, norms, and roles in light of experienced interoceptive sensations so that these social-interactive patterns take on broader meaning and become related to identity and values" (Immordino-Yang & Gotlieb, 2017, p. 361). This perspective aligns with Barrett's (2009) psychological construction approach to emotion, elaborated in Section 2.1.2. This approach posits that emotion involves making meaning of sensory cues informed by past experiences and the present physiological state. At the apex of the spiral, "cultural meaning-making surrounds and guides the development of the social mind, which, in turn, co-opts embodied brain systems and embeds itself within patterns of neurobiological functioning supporting homeostasis" (Immordino-Yang & Gotlieb, 2017, p.361).

Lastly, this model situates “the emotional brain and its physiological regulatory functions ecologically” (Immordino-Yang & Gotlieb, 2017, p.360). According to this model, emotions are constructed by progressing from the lower to the higher levels of the biopsychosocial self as individuals mentally accommodate their interactions with others and integrate their behaviours and thoughts into the broader social context (Immordino-Yang & Gotlieb, 2017). In contrast, the social and cultural contexts at the top of the spiral exert a downward influence on all levels below, and this process of moving down the levels involves inducing emotion and organised action. From the dynamic systems perspective, organised patterns at each level support and constrain functioning at the level below (Immordino-Yang & Gotlieb, 2017).

In conclusion, this framework integrates bodily function, the embodied brain, the social mind, and culturally situated meaning-making, highlighting their dynamic interactions in affective processing. However, as previously noted, it does not adequately account for the brain’s predictive mechanisms, nor does it sufficiently illuminate the ‘real-time’ and ‘here-and-now’ affective experiences that children encounter in social environments.

2.3.2 The conceptual framework of social exclusion in education

The present study proposes a novel conceptual framework that integrates the biopsychosocial framework for affective processing (Immordino-Yang and Gotlieb, 2017), with contemporary insights concerning the Bayesian predictive brain. This framework aims to offer a more nuanced understanding of emotional processes occurring in the ‘here-and-now’, particularly within the context of social exclusion. This enriched framework will integrate ‘feedback loops’ at the intersection of the predictive, embodied brain and immediate contexts (Kim & Sankey, 2022). Furthermore, it will encompass essential principles from the ‘predictive brain’ to clarify how the brain’s anticipatory mechanisms significantly affect the emotional dynamics experienced by victims of social exclusion, where prior experiences shape the individual's anticipation when confronted with the possibility of further exclusion.

The proposed model comprises four distinct levels: the body, the embodied brain, immediate contexts, and broader contexts (refer to Figure 2.3.2.1). Within this framework, social exclusion and its emotional dynamics can be conceptualised as dynamic, embodied processes influenced by the brain's predictive mechanisms and shaped by social and cultural contexts. This framework emphasises the intricate interplay among individual factors, social interactions, and contextual influences that contribute to the emergence of emotions in the context of social exclusion. Figure 2.3.2.1 illustrates that this dynamic system comprises multiple components or subsystems, including the individual, characterised by a physical body and an embodied brain, as well as the immediate and broader contexts. Within each subsystem, numerous components can be identified. The individual, possessing a physical body and an embodied brain, maintains an internal model of the world shaped by prior experiences. The immediate contexts refer to the environments in which children's social interactions occur, such as classrooms, playgrounds, and schools. In contrast, the broader contexts pertain to the expansive societal and cultural milieu, including but not limited to cultural norms, social hierarchies, and power dynamics that influence social experiences. Within the framework of current discourse analysing social exclusion from the victims' perspective, this analysis predominantly highlights aspects such as core affect, the brain's internal model related to social exclusion, along with various contextual elements. It examines how these factors contribute to the Prediction-Feedback (error vs. confirmation) dynamics.

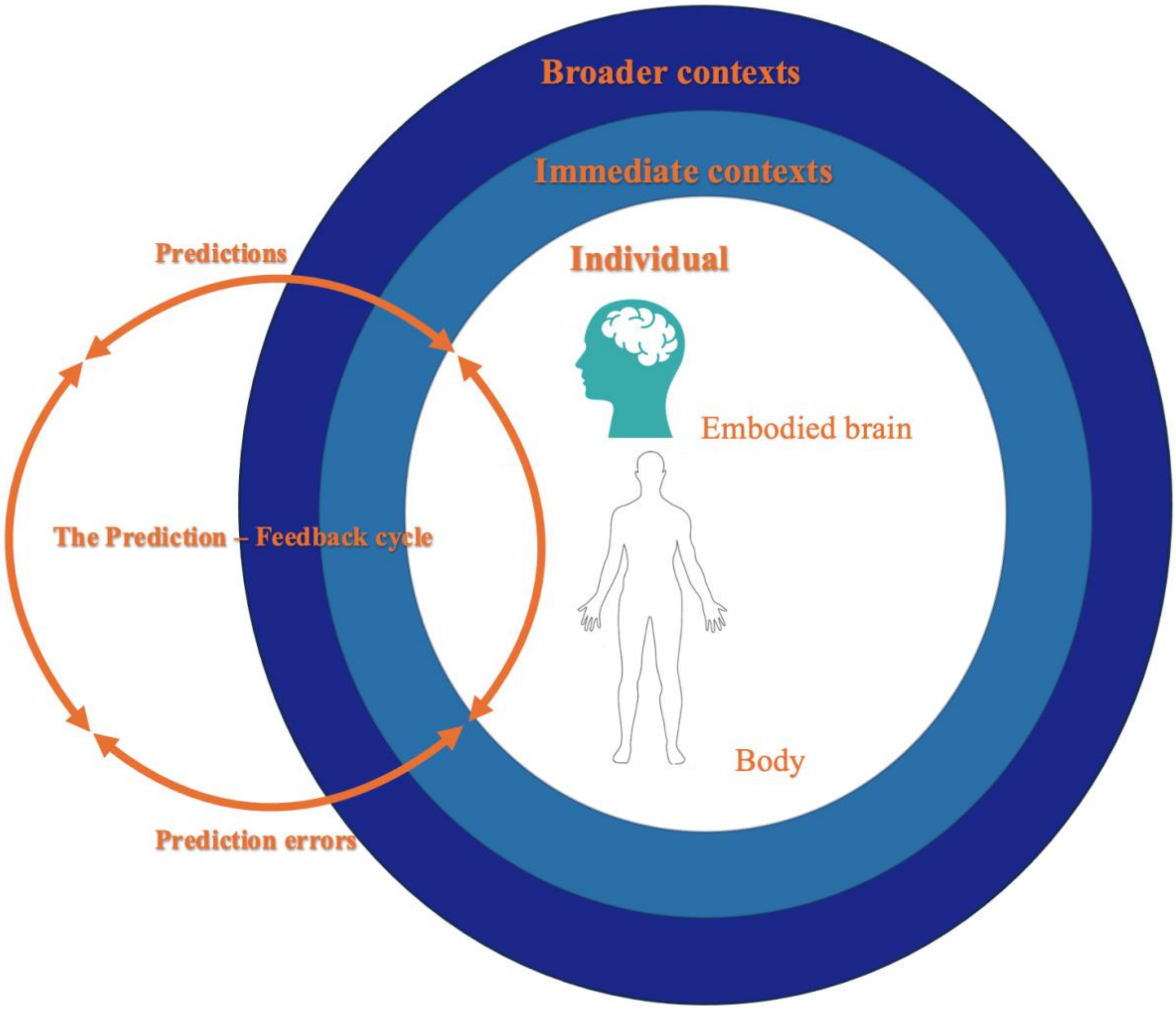


Figure 2.3.2.1 A new conceptual framework on social exclusion

Based on the literature reviews in Sections 2.1 and 2.2, the current conceptual framework for social exclusion posits the following assumptions: (1) Humans are intrinsically social creatures with a profound yearning for belonging; this innate desire is fundamentally an evolutionarily established biological value. (2) The brain constructs and operates an internal model of the world that is shaped by prior experiences and tailored to meet allostatic needs. This internal model is represented as concepts, which are infused with value and enable the brain to predict forthcoming stimuli. (3) Emotions and social exclusion operate as dynamic systems, adhering to the DST principles. We have outlined these assumptions separately for discussion, as though they could function independently. However, as outlined in Section 2.1, it is crucial to recognise the intricate interconnectedness of all fundamental predictive brain mechanisms, including interception, allostasis, value, core affect, and categorisation, which engage in dynamic interactions. For instance, the core affect is intricately linked to allostasis and signifies the embodiment of value established through evolution, accompanying all mental experiences.

Value-laden perception of social exclusion

The first assumption is that humans are inherently social beings with a deep-seated desire for connection, and the longing for belonging is fundamentally an evolutionarily ingrained biological value. This assumption is well-documented in the literature (e.g., Eisenberger, 2013; Leary & Cottrell, 2013; North & Fiske, 2013; Williams, 2009). This corresponds with various traditional theoretical frameworks concerning social exclusion, including the core motive approach to social psychology posited by North and Fiske (2013) and the need-threat model articulated by Williams (2009). According to these authors and numerous others, participation in a social group is crucial for individuals' survival and overall well-being. Hence, being socially included or accepted is an evolutionarily established value. In contrast, being socially excluded or rejected inherently violates this value criterion. Edelman's (1992) theory of neuronal group selection (TNGS) posits that the brain's value system is in continuous communication with other cortical regions to assess the appropriateness of actions in reference to an evolutionarily established biological value. Consequently, actions that fulfil homeostatic requirements are regarded as 'good' to us. Conversely, social exclusion is regarded as 'bad' for us as it violates our essential need for belonging. This judgement of 'badness' manifests as a core affect, the constant homeostatic feelings of displeasure (valence) and agitation (arousal). As Edelman (1992) argued, "behaviour is constrained by ethological factors, among the most important of which are the value systems and homeostatic requirements selected for during the evolution of a species" (p.101). Edelman (1992) posited that the brain categorises internal or external stimuli based on value, indicating that these evolutionarily established values significantly influence perceptions and interpretations. In the context of social exclusion, the salience and emotional intensity associated with the experience are exacerbated due to the perceived threat to the fundamental value of social belonging. This elucidates why even seemingly trivial occurrences of exclusion can elicit pronounced emotional responses. In conclusion, the intrinsic drive for social connection and belonging is a fundamental human necessity deeply ingrained in our evolutionary heritage. This inherent value attributed to social belonging informs our sensitivity to social cues and shapes our emotional reactions to social encounters.

Concept development and social exclusion

According to our second assumption, the human brain constructs and operates an internal model of the world influenced by prior experiences and tailored to allostatic needs. "From birth, the human brain captures statistical regularities in sensorimotor patterns and stores them as internal representations" (Barrett, 2009, p.1292). This vast repository of stored representations allows the brain to "continuously and unintentionally categorise what sensory stimulation means in the present, to make the present state meaningful" (Barrett, 2009, p.1292). When social exclusion occurs in the lives of young children for the first time, specific neural patterns emerge in response to this external stimulus. Given its evolutionarily established biological significance, social exclusion inherently resides within our affective niche, as articulated by Barrett (2018). Consequently, it can potentially influence core affect. Currently, these neural patterns may predominantly manifest as various physiobiological responses in the body (e.g., muscle tension and increased heart rate) and core affect (e.g., homeostatic feelings of displeasure and agitation) within the embodied brain. Numerous conventional theories concerning social exclusion or rejection have articulated some of these immediate consequences. This includes the reflexive phase of Williams's Temporal Model of Ostracism (2001), Richman and Leary's (2009) characterisation of victims' immediate feelings of hurt, as well as the neural mechanisms linked to social pain, as proposed in Pain Overlap Theory (Eisenberger & Lieberman, 2005) and Social Pain Theory (Macdonald et al., 2005).

Moreover, as Edelman (1992) suggests, "neuronal groups that respond initially to a stimulus have, on average, a higher likelihood of responding to a similar stimulus when subsequently presented, but value systems modulate that like" (p. 97). Given the fundamental nature of social exclusion, which contravenes our deep-seated need for belonging, it is more likely that similar neuronal groups initially responding to social exclusion will be reactivated in subsequent instances of social exclusion. Consequently, the previously associated physiobiological changes and feelings of displeasure and agitation are likely to recur. In other words, since the desire for inclusion represents a deeply ingrained evolutionary biological value, we assert that violations of this value (e.g., social exclusion) will yield negative intrinsic and automatic repercussions at the neurobiological level (e.g., physiobiological changes, core affect, etc.). This impact is typically resistant to conscious modification due to their rapid and automatic nature. Therefore, it can be inferred that individuals inherently and unconsciously undergo adverse physiobiological changes and negative affective responses when exposed to social exclusion, such as those addressed in numerous traditional theories regarding social exclusion and rejection in Section 2.2. In this context, even infants or young children, who lack the linguistic ability to articulate this experience as 'social exclusion,' are nonetheless affected by its consequences, albeit at the neurobiological and homeostatic feeling level.

Through repeated social interactions, children cultivate and enhance their concepts of social exclusion. Their comprehension of social exclusion continuously evolves, becoming increasingly tangible and nuanced. However, at the observable or conscious level, not every individual perceives or feels the ‘badness’ of social exclusion. Why? The simple answer is that each person possesses an individualised internal model of the world developed during development. From the perspective of the victim’s predictive Bayesian brain, social exclusion cannot merely be defined as an external occurrence. Instead, in addition to external events, individuals have developed embodied concepts about or related to social exclusion based on past experiences. Here, the concept refers to “a collection of embodied, whole-brain representations” (Barrett, 2017, p. 12) that predict future events and guide actions in the service of allostasis, accessible to consciousness as homeostatic feeling or core affect.

As children progress through their developmental journey, their embodied concepts concerning social exclusion encompass not only negative intrinsic and automatic consequences at the neurobiological level but also more intricate psychological transformations, along with observable behaviours at a more conscious level. During this course, children might display various response patterns to social exclusion depending on their individual experiences within the context of social exclusion, such as those discussed in Section 2.2. Since social exclusion violates our fundamental needs for belonging, all victims of it will inevitably experience the negative neurobiological and affective consequences of this violation. Nevertheless, it is important to note that not all children who endure social exclusion exhibit adverse behaviours or experience long-term negative consequences. What explains this phenomenon?

On one hand, the brain’s internal model of social exclusion is not merely an abstract representation; rather, it is profoundly rooted in bodily experiences. Core affect, which reflects the body’s internal state, provides a continuous stream of information that shapes emotional experiences and influences social behaviour. For example, feelings of anxiety or discomfort arising from interoceptive signals may affect a child's social interactions and contribute to withdrawal or avoidance behaviour. However, the brain's internal model is not solely predicated on individual experiences; it is also influenced by social interactions, cultural norms, and values. This internal model, encompassing social concepts, is in a constant state of adaptation and reorganisation based on new experiences and prediction errors. An updated internal model can positively or negatively influence future social behaviours. For instance, if children are taught how to respond appropriately to social and emotional challenges related to social exclusion, they are more likely to develop a repertoire of strategies to manage this issue, thereby reducing the likelihood of experiencing persistent social exclusion and its deleterious effects. In contrast, without adequate support, they may become long-term victims of social exclusion, suffering its adverse impact across various domains. Furthermore, throughout individual development, the value system continuously evolves; "the salience of an event is determined not only by its position and energy in the physical world, but also by the relative value it has been accorded in the past history of the individual animal as a result of learning" (Edelman, 1992, p.118). In other words, identical stimuli may hold significant relevance for one individual while being perceived inconsequential by another. What might be meaningful for one person today may not retain the same importance at another time if its value changes.

Fundamentally, all individuals have an intrinsic desire to belong to social groups. The denial of belonging resulting from social exclusion precipitates a wide range of adverse effects on the victim at both observable and covert levels. At the observable level, these effects may manifest as negative behaviours, psychological issues (e.g., depression, anxiety), or physical ailments (e.g., headaches or other symptoms). At the covert level, the impact is reflected through core affect. Moreover, considering that core affect is contingent upon interoception, physiological functions significantly influence all mental experiences, including the comprehensive experience of social exclusion. For example, if a student has had insufficient sleep the previous night, he may arrive at school feeling fatigued and irritable. Consequently, when this student encounters social exclusion, his reaction to this adverse experience is likely to be more pronounced and predominantly negative. This explains why the same individual may react differently to social exclusion when other contextual factors remain unchanged. This further underscores the significance of the body in students' learning and well-being in school.

The Prediction – Feedback cycle

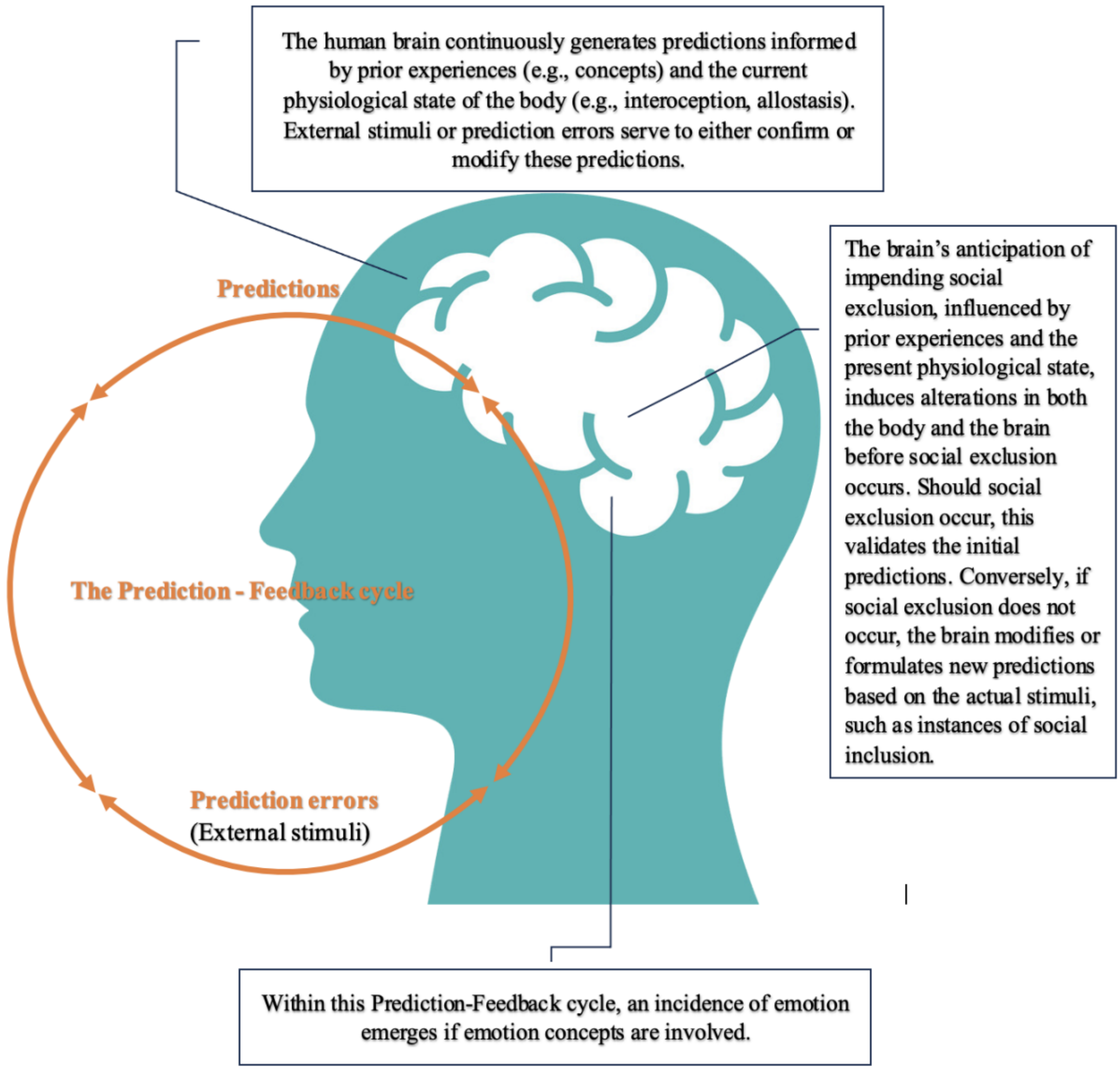


Figure 2.3.2.2 The Prediction – Feedback cycle

The preceding discourse examined the brain's internal representation of the world. In the context of social exclusion, this internal representation encompasses concepts related to social exclusion. We shall now delve deeply into the interactions between the brain's internal predictions of the world and the perceived world through the lens of 'prediction-feedback' dynamics. As illustrated in Figure 2.3.2.2, from the predictive brain perspective, if an individual anticipates whether he or she will experience social exclusion in a certain context based on past experiences (the brain's internal prediction regarding social exclusion), from that individual's viewpoint, social exclusion has already occurred, as the prediction has initiated various neural and physiological changes internally. In other words, at the bodily functioning level, predictions of social exclusion have altered the internal landscapes before actually confronting social exclusion. The actual incoming sensory input (e.g., being socially included or excluded) will either confirm or disconfirm this prediction. If it is confirmed, all associated neural, biological, and psychological actions will be validated and continued. Individuals who frequently experience social exclusion are more likely to predict exclusion in certain social contexts. Due to the nature of embodied predictive brains, these individuals will repeatedly experience the consequences of social exclusion at a neurobiological level before it actually occurs. If the prediction is not confirmed by external stimuli, the brain and body will respond accordingly and modify the prediction to match the actual stimuli. Either way, repeated experiences of social exclusion or inclusion can lead to updates in concepts related to social exclusion, such as social exclusion itself, belonging, self-worth, social threat, and so on.

During the Prediction-Feedback process, the involvement of emotional concepts may elicit an incidence of emotion. For example, when someone anticipates social exclusion, this expectation activates physiological and neurological reactions. Physiologically, one might experience an increased heart rate, faster respiration, heightened muscle tension, and possibly even abdominal discomfort. According to Barrett's construction theory of emotion, if the brain categorises or labels these sensations as anger, leveraging the concept of anger informed by previous experiences in similar scenarios, should this individual face social exclusion, they will likely feel angry about it. Conversely, if they are included, a prediction error occurs. The brain will adjust its predictions and send new commands to the body, resulting in different physiological responses, such as a slower heart rate and respiration, relaxed muscles, and alleviated abdominal discomfort. These updated sensations can then be categorised using a different emotional concept drawn from personal experiences in similar situations. If the concept of joy is engaged, the emotion of joy will be constructed in this context. Regardless of the emotion ultimately constructed during the Prediction-Feedback dynamics surrounding social exclusion, the anticipation of social exclusion will inevitably generate negative physical sensations and homeostatic feelings, as it contradicts our intrinsic value of belonging. The reality of social exclusion will confirm this prediction, causing the initial bodily changes and homeostatic feelings to contribute to the construction of anger. In contrast, actual social inclusion will modify and update predictions, leading to new bodily changes and homeostatic feelings that contribute to the emergence of a new emotion, perhaps joy. Either way, the brain's predictions or anticipations regarding potential social exclusion significantly impact the subsequent emotional dynamics.

The preceding discussion concerning the Prediction-Feedback cycle may seem linear, in which the feedback (prediction error) either affirms or contradicts the initial prediction. It is crucial to note that both prediction and feedback occur concurrently. As elaborated in Section 2.1.2, when a prediction error manifests, the brain activates three mechanisms to minimise it: (1) Prediction errors are transmitted from the mid and posterior insula to the deeper agranular visceromotor cortices, where adjustments to the predictions can be made before being relayed back to the mid and posterior insula, thereby reducing subsequent prediction errors; (2) simultaneously, the visceromotor regions issue new predictions to the body to elicit the anticipated sensations; (3) the visceromotor circuitry can modulate how the brain prioritises incoming sensory information (Barrett & Simmons 2015). Essentially, "perception and action are tightly coupled, with both arising from the brain's hypotheses about the world and constrained by sensory inputs from the world" (Barrett & Simmons, 2015, p. 415).

If an individual does not categorise a specific incident as social exclusion, that individual does not perceive themselves as socially excluded, at least on a cognitive and more conscious level. Nonetheless, as mentioned earlier, at the physiological level, all victims of social exclusion experience various negative physiobiological changes. Although these physical sensations may differ among individuals, their core affective experience is similar; in other words, they all 'feel bad' about this experience neurobiologically. However, the more apparent consequences of these adverse experiences can be mitigated through learning. This highlights the individual differences encountered across various domains when confronted with social exclusion. It also leads to the final assumption of our model.

A dynamic perspective of social exclusion

The final, yet equally significant, assumption of our model posits that social exclusion is a phenomenon viewed as a dynamic system, adhering to the principles of DST. As illustrated in Figure 2.3.2.1, each element within our framework—including individuals, immediate contexts, and broader contexts—interacts with and constrains one another, underscoring the integrated nature of the overarching phenomenon of social exclusion. This concept is exemplified by the nested cycles of the three distinct levels of our model and the Prediction-

Feedback dynamics that operate across all three levels. It is important to note that although the Prediction-Feedback dynamics predominantly function at the intersection of individual and immediate contexts, broader contexts also influence these dynamics. For instance, varying cultural norms concerning emotional expression and regulation can impact how individuals perceive and interpret their bodily sensations, leading to discrepancies in the neural correlates of emotions (Immordino-Yang & Gotlieb, 2017; Kim & Sankey, 2022).

From a dynamic systems perspective, self-organised patterns (e.g., attractor states) at each hierarchical level enhance and constrain lower-level functioning (Immordino-Yang & Gotlieb, 2017). At the core of this framework lies the individual, characterised by a physical body and an embodied brain (see Figure 2.3.2.2). In circumstances of social exclusion, the internal model of the individual's brain—shaped by personal factors, social interactions, and contextual influences—generates predictions regarding social engagements. These predictions are subsequently compared to actual social experiences, potentially resulting in prediction errors. Such prediction errors are processed and can lead to modifications of the internal model, updating related social concepts. The revised internal model subsequently guides future social behaviours, which, in turn, feeds back into the cycle, potentially reinforcing patterns of exclusion. For example, experiences of exclusion may contribute to the formation of negative self-concepts and beliefs about social relationships, potentially influencing future interactions and perpetuating cycles of exclusion (Juvonen, 2013). In this manner, the individual simultaneously influences the immediate context by interacting with their environment. As Immordino-Yang and Gotlieb (2017) elucidated, "the embodied functions of the brain, in turn, contain and support the social functions of the mind … ultimately the adoption of social beliefs, norms, and roles" (p. 360). These social beliefs, norms, and roles constitute elements within the immediate and broader contexts of our framework; they also impose constraints on the development of the internal model of social exclusion, along with all processes occurring at the individual level. For instance, the interpretation and significance assigned to social experiences, such as exclusion, are influenced by cultural values, beliefs, and practices (Immordino-Yang & Gotlieb, 2017). Diverse cultures may emphasise distinct social norms and expectations, resulting in variations in emotional and behavioural responses to exclusion.

As previously indicated, real-time interactions with peers involve the Prediction-Feedback cycle, significantly influencing an individual's embodied notion of social dynamics. Throughout development, specific self-organising patterns within each level attain greater stability through consistent repetition and reinforcement. Our earlier exploration centres on the dynamics of emotional construction in real-time, particularly emphasising emotional concepts and the current physiological state, especially in the context of social exclusion. This discussion primarily underscores both the individual and immediate context levels. Throughout the developmental trajectory, various factors within each level of our framework are subject to modifications and transformations over time. For instance, at the individual level, a person's emotion and social exclusion concepts undergo continuous evolution and refinement. For instance, as children mature, they develop a more sophisticated and nuanced ability to reason about social exclusion across diverse contexts (Mulvey, 2016). Consequently, these developments lead to updates in emotional and social concepts relevant to the specific context. Furthermore, children exhibit varying levels of competence when confronting the challenges associated with social exclusion, depending on their personal experiences, such as the adequacy of support received from peers and educators in educational settings. On an individual basis, prolonged exposure to social exclusion may yield increasingly stabilised adverse effects across neurobiological, psychological, emotional, and behavioural domains. As detailed in Section 2.3, these detrimental effects on victims are comprehensively documented in the literature.

At the level of immediate context, as children progress through their educational journeys, their immediate environments expand—from familial settings to educational institutions and larger communities—imposing increasingly rigorous demands upon them. Ultimately, at broader contextual levels, societal and cultural transformations are perpetually evolving. Collectively, these alterations, occurring at both the individual and contextual dimensions, may introduce additional challenges for individuals experiencing social exclusion. Moreover, elements within these contextual levels can become progressively rigid and resistant to change. For example, some individuals may regularly face exclusion within a classroom, or particular detrimental interaction patterns may become entrenched, thereby exacerbating the circumstances of social exclusion. Furthermore, a persistent cultural bias associated with social exclusion may be sustained. The changes implemented at each level of our framework can significantly influence the emotional experiences of individuals affected by social exclusion.

In conclusion, this section presents a novel, enriched framework of social exclusion that integrates essential principles derived from the predictive brain and DST. The originality of our model is underscored by our focus on the Prediction – Feedback cycle in shaping the emotional and social dynamics at the interface between individuals and their contexts. Through a predictive brain lens, we elucidate how the 'here-and-now' emotional dynamics arise from the intricate interactions among past experiences, current bodily states, and contextual factors. More specifically, we examine how the brain's anticipation or prediction of social exclusion influences the subsequent affective processes in this context. Consequently, this predictive perspective informs the research design and data collection, which will be elaborated upon in the subsequent methodology chapter.

2.4 Using EEG to unpack the neural correlate of social exclusion

A variety of brain imaging techniques have been employed in the field of educational neuroscience, including EEG, magnetoencephalography, functional magnetic resonance imaging, and functional near-infrared spectroscopy (Orovas et al., 2025). Each of these methodologies presents unique advantages and limitations for examining the brain's functionality when participants engage with tasks relevant to educational research questions. In the present study, EEG data were triangulated with self-reported data to explore the neural dynamics associated with the anticipation of social exclusion and post-hoc feedback appraisals, as well as how these real-time neural dynamics correlate with self-reported distress following exclusion by unfamiliar peers and the children's sense of school belonging. Therefore, the literature review presented below will introduce EEG and ERP techniques with a specific focus on how they can enhance educational researchers' understanding of children's social exclusion.

2.4.1 EEG and ERP techniques

Neural Origins of EEG signals

Neurons are specialised cells in the nervous system that transmit information through electrical and chemical signals. Each neuron can interact with up to 10,000 neighbouring neurons via two types of branches: axons and dendrites (Carter, 2010). A small gap, known as the synapse, exists where an axon connects with a dendrite (Carter, 2010). When at rest, a neuron's membrane potential is negative, characterised by a higher concentration of positively charged sodium ions (Na+) outside and slightly larger positively charged potassium ions (K+) inside (Panksepp, 1988; Kim & Sankey, 2022). These ions are in constant motion across the cell membrane. The entry of sodium ions into the cell decreases internal negativity, a process called depolarisation. If depolarisation exceeds a certain threshold, the internal negativity rapidly shifts to positivity, prompting the neuron to fire an action potential (Panksepp, 1988; Kim &

Sankey, 2022). This action potential, the electrical impulse resulting from the swift change from a negative to a positive internal charge, travels along the axon to the synapse, impacting the activity of postsynaptic neurons. Following the influx of Na+ ions, potassium ions (K+) exit the cell to return to the resting membrane potential, preparing the neuron for subsequent firing (Panksepp, 1988; Kim & Sankey, 2022). This recovery phase is referred to as repolarisation. Conversely, if the internal negative charge of a neuron escalates, firing is inhibited, leading to a state of inhibition (Panksepp, 1988; Kim & Sankey, 2022).

When action potentials reach the synapse, they convert frequency-coded electrical signals into chemical signals that prompt the release of various neurotransmitters (Panksepp, 1988; Kim & Sankey, 2022). These neurotransmitters cross the synapse and bind to receptors on the postsynaptic cell's membrane, allowing the influx and efflux of ions in the neuron (Kim & Sankey, 2022). A positively charged ion current enters the postsynaptic neuron from the extracellular space, resulting in increased negativity around the apical dendrites of the receiving cell (Kim & Sankey, 2022). Meanwhile, positively charged ions exit the cell body and basal dendrites to complete the circuit, leading to increased positivity in that area (Kim & Sankey, 2022). This current flow creates a small dipole or electrical field around the neuron, known as postsynaptic potential (Kim & Sankey, 2022).

Both action potentials and postsynaptic potentials reflect electrical activity in the brain; however, most EEG studies primarily detect signals from postsynaptic potentials (Luck, 2014). Specifically, scalp EEG signals mainly originate from pyramidal cells, which have a single apical dendrite and a pair of basal dendrites (Luck, 2014). The electrical field generated by an individual neuron is too weak to be registered at the scalp. However, when numerous neurons with parallel orientations fire simultaneously, their individual electrical fields combine, leading to stronger EEG signals that can be recorded on the scalp using EEG equipment (Cohen, 2014). When this occurs, these signals aggregate and propagate nearly at the speed of light throughout the brain, meninges, skull, and scalp (Luck, 2014). Thus, EEG provides “a direct, instantaneous, millisecond-resolution measure of neurotransmission-mediated neural activity” (Luck, 2014, p.12).

Event-related potential (ERP) technique

The event-related potential (ERP) technique is a valuable tool that can be used to identify the neural activities associated with specific states or cognitive/affective processes. This is achieved by using the process of ‘time-locking’ and ‘averaging’ (Kim & Sankey, 2022; Luck, 2014). An ERP component can be operationalised as “a set of voltage changes that are consistent with a single neural generator site and that systematically vary in amplitude across conditions, time, individuals…is a source of systematic and reliable variability in an ERP data set” (Luck, 2014, p. 68). In other words, the ERP components are time-locked to specific events. In the current study, as elucidated in Chapter 3, we collected EEG data while participants engaged in the social exclusion experiment known as the SJP. This design allowed us to differentiate the experience of social exclusion into two distinct phases: the anticipation of social feedback (acceptance versus rejection) and the subsequent feedback appraisal. Given its exceptional temporal precision and accuracy (Cohen, 2014), EEG and ERPs were particularly well-suited for the present investigation. More specifically, we extracted relevant ERP components that are time-locked to the onset of two critical events in the SJP: participants providing predictions, which triggered the feedback anticipation stage, and participants receiving peer feedback, which initiated the feedback appraisal stage. ERPs facilitated the analysis of underlying neural dynamics in real time during both the feedback anticipation and post-hoc feedback appraisal phases, which is essential for addressing our Research Question 2.

As discussed in Section 2.4.3, various ERP components have been employed to investigate the neural dynamics underlying the anticipation of social feedback, including the SPN and feedback-related potentials, such as the FRN, P3, and LPPs.

2.4.2 Research paradigms in ERP studies on social exclusion

Two prominent paradigms employed in EEG/ERP research on social exclusion include the *Cyberball Task*, developed by Williams and Jarvis (2006), and the *SJP* conducted by Somerville et al. (2006). The Cyberball is a computer-simulated ball-toss game designed to simulate social exclusion through interactions with two virtual avatars. This task comprises two conditions: social inclusion and social exclusion. In the social exclusion condition, participants either do not receive the ball at all or receive it very infrequently. The SJP requires participants to predict social outcomes and subsequently receive feedback, which is randomly generated by the computer. This design facilitates the investigation of expectations surrounding social evaluation. During these experiments, participants encounter experiences of social exclusion, rejection, or evaluation while their brain activity is monitored using EEG. Additionally, to evaluate participants' subjective feelings of distress following experiences of social exclusion during the experiment, researchers typically employ the Need Threat Scale (NTS), based on Williams's (2009) need threat model (e.g., Baddam et al., 2016; Crowley et al., 2010; Tang et al., 2019; Van Noordt et al., 2015). Considering their prevalence in ERP studies related to social exclusion, this literature review shall concentrate on ERP investigations utilising the Cyberball or SJP tasks.

2.4.3 ERP components that index neural processes initiated from social exclusion experiences

In academic literature, various ERP components have been utilised to investigate the neural correlates associated with social exclusion. This literature review will concentrate on the following components: SPN, FRN, P3/P300, and LPPs. The ERPs analysed in this study encompassed temporal intervals extending from 200 milliseconds prior to social exclusion, exemplified by the SPN, to 2000 milliseconds following the event, which included the FRN, P3, and LPP. This delineated temporal range facilitated a comprehensive examination of the neural mechanisms engaged prior to social exclusion, as well as the diverse neural correlates that emerged subsequently. Furthermore, the selection of these particular ERP components for the literature review enables us to address Research Question 2 comprehensively.

Stimulus preceding negativity (SPN)

Humans apply past and present information to inform future behaviour. As elaborated in Section 2.1.2, from the perspective of an embodied predictive brain, the brain perpetually forecasts and prepares for forthcoming events, executing effective actions based on prior and present experiences. This predictive mechanism is intricately linked to interoception and core affect. Accurate forecasting is crucial for the brain to prepare and generate adaptive responses while conserving energy. One of the ERP components frequently associated with anticipation or preparation is the SPN (Ohgami et al., 2004). The SPN is classified as a type of Slow Cortical Potential (SCP), and it does not pertain to motor preparation; rather, it is interpreted as a manifestation of control over response timing and attention to the anticipated stimuli (Böcker et al., 2001). Furthermore, it has been proposed that the SPN indexes "the awareness of interoceptive information that precedes feedback stimuli" (Kotani et al., 2009, p. 75).

Although SPN morphology depends on specific task parameters, numerous studies have shown that SPN predominantly manifests in anticipation of stimuli with affective or motivational valence (Böcker et al., 2001; Böcker et al., 2003). For instance, the SPN exhibited significant amplification when participants were presented with rewards (Böcker et al., 2001; Ohgami et al., 2004) or stimuli that elicited negative emotions (Böcker et al., 2001; Michalowski et al., 2015), in contrast to situations lacking rewards or involving neutral stimuli. Additionally, the SPN observed in middle childhood children was similarly heightened in response to social conditions compared to non-social conditions (Stavropoulos & Carver, 2014a; Stavropoulos & Carver, 2014b). Given that social cues inherently possess emotional valence and are more salient, it can be inferred that SPN is susceptible to enhancement by affective or motivational stimuli.

Another critical research dimension is the influence of the informational value of feedback on the SPN. For instance, Kotani et al. (2003) discovered that SPN amplitude was the highest in the reward/high information condition, significantly larger than in the no-reward/high information condition. No difference in SPN was observed between reward and no-reward conditions in the low-information scenario (Kotani et al., 2003). Furthermore, there were no significant main effects of information across the reward and no-reward conditions (Kotani et al., 2003). The researchers proposed that the SPN may have a motivational threshold that is surpassed only when participants receive detailed information that increases their reward, allowing the motivational level to exceed this threshold and enhance SPN (Kotani et al., 2003). They concluded, “the informational level of feedback stimuli affects the subjects’ motivation and that the reward and informational manipulation differently affect the motivation and SPN amplitude” (Kotani et al., 2003, p. 825).

Catena et al. (2012) noted that Kotani et al. (2003) present seven potential outcomes within the rich feedback condition, contingent on the level of correctness, and posited that uncertainty is higher in this condition. Therefore, Catena et al. argued that it is not the richness of information, but the uncertainty linked to the outcome that elevates the SPN in Kotani et al.'s study. They added, "The effect of information was significant only in the reward condition … which is compatible with the idea that the effect of uncertainty increases when the individual is highly motivated. Nevertheless, motivation and uncertainty are related but separable dimensions" (Catena et al., 2012, p.9). Thus, the certainty associated with a stimulus was another significant factor in eliciting the SPN. Research indicates that SPN amplitudes tend to be greater prior to unpredictable—thus uncertain–feedback. For example, researchers discovered that the SPN was larger preceding uncertain stimuli than predictable ones (Catena et al., 2012) and that the SPN for uncertain threats was larger compared to certain threats and safety (Tanovic et al., 2018; Tanovic & Joormann, 2019). Collectively, these studies imply that the SPN is more pronounced under conditions where outcomes are uncertain than when outcomes are certain.

Researchers employing the SJP investigated the influence of prediction valence on the SPN. For example, a study involving 31 adult female participants conducted by Van der Molen et al. (2014) found that the SPN amplitudes were significantly more negative when anticipating social acceptance than rejection. A recent SJP study with healthy young adolescents revealed a developmental change in the SPN during adolescence, with older adolescents showing reduced overall SPN amplitudes (Topel et al., 2021). However, this study failed to identify a significant SPN amplitude difference between anticipation of acceptance and rejection (Topel et al., 2021). Furthermore, the research found a significant correlation between the level of pubertal development and SPN amplitude during the anticipation of social feedback (Topel et al., 2021).

Researchers also explored how SPN correlates with the anticipation of social feedback and various emotional states. For instance, Jackson (2019) reported that the adults' SPN in anticipation of unpredictable feedback was associated with greater daily experiences of distress emotions—specifically anxiety, fear, and distress. Van der Molen et al. (2014) observed a notable correlation between the SPN and Fear of Negative Evaluation, specifically when participants predicted social acceptance. This correlation was absent when they anticipated social rejection (Van der Molen et al., 2014). Furthermore, the SPN following predictions of social acceptance exhibited larger amplitudes in participants with elevated levels of FNE (Van der Molen et al., 2014). Topel and his colleagues (2021) found that the SPN was significantly larger for adolescents with higher levels of social anxiety, irrespective of anticipating acceptance or rejection feedback. Their findings further revealed that the influence of social anxiety effects on the SPN was particularly significant for females as opposed to males (Topel et al., 2021).

Feedback related negativity (FRN)

FRN is a frontocentral negative component peaking approximately 250 milliseconds after feedback onset. It is time-locked to external feedback that signifies either a contextual outcome (e.g., win or loss) or a behavioural result (e.g., correct or incorrect) (van Noordt & Segalowitz, 2012). The prevailing literature on rewards illustrates that the FRN encodes feedback in a binary fashion, distinguishing between positive and negative outcomes and comparing superior and inferior results against expectations (see Ballebaum et al., 2010, for a review). For instance, the FRN consistently exhibits larger amplitudes for reward-related feedback compared to non-reward feedback (Ballebaum et al., 2010) and generally manifests an increased amplitude in response to negative relative to positive feedback, regardless of the feedback modality (see Ullsperger et al., 2014, for a review). Furthermore, the FRN encodes a quantitative reward prediction error, influenced not solely by the outcomes but also by the stimuli predicting them (Walsh & Anderson, 2012). Similarly, the FRN is consistently amplified for unexpected outcomes (Ullsperger et al., 2014) and exhibits greater amplitude for lower probabilities, especially with less expected negative outcomes (Ballebaum et al., 2010). Numerous performance monitoring studies have also established that feedback-related brain activity is sensitive to prediction errors (Walsh & Anderson, 2012). Collectively, FRN demonstrates sensitivity to the valence, congruency and probability associated with outcomes while processing both rewarding and non-rewarding stimuli, as well as to predictions concerning these outcomes (Walsh & Anderson, 2012).

FRN has been subject to extensive examination in social evaluative feedback. The existing literature employing the SJP posits that the FRN serves as an index for the valence processing of social-evaluative feedback (Dekkers et al., 2015; Kortink et al., 2018; Van der Molen et al., 2014). Within this field, researchers commonly concentrate on investigating the influence of social feedback (Van der Molen et al., 2014) or the congruence/incongruence between social predictions and feedback concerning these evaluative processes (Dekkers et al., 2015; Gu et al., 2020; Kortink et al., 2018; van der Molen et al., 2017; van der Molen et al., 2018; van der Veen et al., 2016). For example, in studies with adult samples, investigators have shown that the FRN amplitudes were significantly greater for unexpected compared to expected feedback, regardless of its valence (Dekkers et al., 2015; Kortink et al., 2018; Gu et al., 2020; van der Molen et al., 2017; van der Molen et al., 2018; van der Veen et al., 2016) or the contextual framework (i.e., social versus non-social) (Dekkers et al., 2015). Interestingly, the most pronounced FRN amplitudes were observed in response to unexpected rejection feedback (Dekkers et al., 2015; Kortink et al., 2018; van der Molen et al., 2017). However, when only analysing the impact of feedback valence on the FRN, no significant difference was found between acceptance and rejection feedback (Van der Molen et al., 2014).

Moreover, a study of adults with elevated social anxiety found that the FRN elicited by unexpected acceptance was significantly greater than that elicited by unexpected rejection; this distinction was not present for expected feedback (Gu et al., 2020). Conversely, the group with low social anxiety exhibited no significant interaction between social feedback and prediction-feedback congruence (Gu et al., 2020). The authors suggested that individuals with high social anxiety may harbour a more pessimistic perspective than what is depicted in their self-reports. They may implicitly anticipate social rejection despite explicitly predicting social acceptance in the experiment. This underlying belief is evident in their FRN — 'I will be rejected'. Consequently, the experience of unexpected rejection did not contradict their prior expectations to the same extent as unexpected acceptance, as shown by the diminished FRN observed in this group (Gu et al., 2020).

In a separate investigation utilising the SJP, the FRN amplitudes did not exhibit significant differences between individuals with social anxiety and those without (van der Molen et al., 2018). Using the same paradigm, van der Molen et al. (2014) observed that the FRN amplitudes corresponding to incongruent feedback were more significant than those related to congruent feedback; nonetheless, this difference was not statistically significant. The authors suggested that the lack of a substantial incongruency effect might be connected to the incongruent feedback in the SJP not accurately reflecting task performance, considering that the FRN may also signal poor performance (van Noordt & Segalowitz, 2012). In conclusion, the FRN shows increased sensitivity to unexpected feedback, regardless of its valence, compared to anticipated feedback during social feedback processing. This FRN response may signify the early detection of incongruence (Dekkers et al., 2015) and encapsulates a prediction error, underscoring an unexpected positive or negative outcome (van der Veen et al., 2016).

This interpretation aligns with the Predictions of Response–Outcome (PRO) theory proposed by Alexander and Brown (2010). The PRO model posits that the medial prefrontal cortex (mPFC) plays a crucial role in indicating response-outcome predictions, which encompass two interacting components. The first component of the mPFC is responsible for learning to anticipate the probabilities of various potential outcomes of a planned action, independent of valence and rooted in past experiences. Conversely, the second component identifies discrepancies between actual outcomes and expected results, refining predictions and enhancing the actor's ability to forecast more accurately. "The PRO model reinterprets mPFC effects as reflecting a prediction of how likely an adverse outcome is, but more generally, anticipated outcomes may be desirable as well as undesirable" (Alexander & Brown, 2010, p.667).

P3/P300

P3 is a large positive peak occurring approximately 300 to 800 milliseconds following stimulus onset (Themanson et al., 2015) and is observed in stimulus discrimination tasks (Polich, 2007). Polich (2012) suggests, "the P300 is comprised of a P3a that results from an early attention-related process stemming from a working memory representational change, and P3b occurs when the attention-driven stimulus signal is transmitted to temporal and parietal structures" (p. 180). P3 and its underlying subprocesses might reflect rapid inhibition of neural activity to facilitate the transmission of stimulus/task information from frontal (P3a) to temporal-parietal (P3b) locations (Polich, 2007;2012). Considering that P3a responds sensitively to unexpected or significant events while P3b reflects the updating of working memory (Folstein & Van

Petten, 2008), the P3 complex may indicate both prediction/feedback and prediction error/feedforward neural processes.

The P3 amplitude demonstrates sensitivity to various factors, including stimulus probability—specifically, temporal probability—resource allocation, uncertainty (Luck, 2014), and task relevance (Folstein & Van Petten, 2008). Its latency is frequently employed to ascertain the categorisation or evaluation time of stimuli (Folstein & Van Petten, 2008; Luck, 2014). These attributes render the P3 valuable in examining crucial concepts within emotional studies. For instance, latency may be scrutinised to evaluate the duration necessary for distinguishing between exclusionary and inclusionary events or to explore the correlations between prediction and prediction error by observing anticipatory neural activity. Unfortunately, the current literature on social exclusion predominantly focuses on P3 amplitude, leaving its temporal characteristics largely underexplored.

The P3 family demonstrates sensitivity to exclusionary events and exclusion conditions. For example, within the Cyberball paradigm, researchers observed that exclusionary events (e.g., not receiving the ball) elicited varied neural activity patterns indexed by P3b and P3a, both at a macro-level (comparing overall inclusion and exclusion conditions) and at a micro-level (distinguishing between discrete inclusionary and exclusionary events) (Crowley et al., 2010; Gutz et al., 2011; Themanson et al., 2013; 2015). At the macro-level, both P3a and P3b exhibited heightened activity in the exclusion condition, especially when the likelihood of receiving the ball was low (Gutz et al., 2011). Notably, this effect became even more pronounced when participants received the ball during the exclusion condition, indicating a violation of their expectations, as participants anticipated not receiving it during the exclusion block (Gutz et al., 2011).

At the micro-level, the findings regarding both P3a and P3b exhibit inconsistency. Specifically, regarding the P3b component, exclusionary events evoked smaller P3b amplitudes, irrespective of the overall inclusion and exclusion blocks within the Cyberball task, as evidenced in several studies (Gutz et al., 2011; Themanson et al., 2013; Themanson et al., 2015). In contrast, other research indicated that larger P3b amplitudes were elicited during the exclusion block as opposed to the inclusion block (Crowley et al., 2010; Themanson et al., 2013). Similarly, the results concerning P3a are mixed; one study indicates that inclusionary events are associated with larger P3a amplitudes (Gutz et al., 2011), while another study presents an opposing trend, reporting that exclusionary events elicited larger P3a amplitudes (Themanson et al., 2015). Considering the various modifications of this widely recognised social exclusion paradigm, the Cyberball task, these mixed findings may reflect methodological differences within the existing literature on social exclusion.

In addition to the Cyberball paradigm, the SJP was also utilised to examine social exclusion, particularly concerning adult samples. Similar to the Cyberball studies, SJP research found that violations of anticipation may alter the P3 complex. Within this domain, findings on the impact of congruence on P3 amplitudes show considerable variability. Some studies reported no significant differences in P3 amplitudes between unexpected and expected feedback or between positive and negative social feedback (van der Molen et al., 2014). Conversely, others discovered that anticipated social acceptance elicited a significantly larger P3 amplitude compared to all other conditions, including expected rejection, unexpected acceptance, or rejection (Kortink et al., 2018; van der Veen et al., 2014; 2016;2019). In contrast, Dekker et al. (2015) found no increase in P3 response to expected social acceptance feedback; however, they noted a stronger late P3 (425 – 650 ms) amplitude for unexpected feedback compared to expected feedback (Dekker et al., 2015). The pronounced P3 effect observed later in response to unexpected feedback may indicate the engagement of prediction-error-related update processes, where the brain adjusts its predictions to minimise prediction errors for subsequent moments, as posited by the EPIC model.

Late positive potential (LPP)

The LPP is an event-related brain potential that is particularly well-suited for assessing affective processes, as it indicates prolonged attention directed toward emotional content (Speed et al., 2015). It is sensitive to the valence of stimuli and is notably more pronounced for emotional (e.g., pleasant or unpleasant) than for neutral stimuli. This includes affective images (Babkirk et al., 2015; DeCicco et al., 2012; Dennis & Hajcak, 2009; Hajcak et al., 2013; Hajcak & Dennis, 2009; Solomon et al., 2012; Speed et al., 2015), facial expressions (Chronaki et al., 2018; MacNamara et al., 2016), lexical items (Fischler & Bradley, 2006; Schindler et al., 2019), and hand gestures (Flaisch et al., 2011).

The LPP sensitivity to valence has exhibited remarkable robustness in children, with effects noted in individuals as young as five years old (DeCicco et al., 2012), serving as a reliable trait-like indicator of emotional processing (Hajcak et al., 2013). Studies investigating the LPP through image viewing tasks consistently demonstrate that emotional images elicit larger LPP responses among children across various age groups, including those aged 5 to 7 years (DeCicco et al., 2012), 9 years (Kujawa et al., 2013), 8 to 13 years (Kujawa, Klein et al., 2012), and individuals aged 7 to 19 (MacNamara et al., 2016). Furthermore, the LPP is sensitive to the direction of visual attention within unpleasant images, showing reduced LPP amplitudes when attention is directed towards relatively low-arousal areas instead of more arousing regions of these unpleasant images (Hajcak et al., 2009; Hajcak et al., 2013). Collectively, substantial evidence indicates that the LPP in children responds to stimuli characterised by emotional valence.

The LPPs have also been utilised as a neural indicator of cognitive reappraisal in children performing cognitive reappraisal tasks. Some studies indicate that reappraisal leads to the alternation in the emotion regulation, demonstrating a reduction in LPP amplitudes (DeCicco et al., 2014; Dennis & Hajcak, 2009; Leventon & Bauer, 2016). However, the replicability of this reduction in amplitude has been inconsistent across studies (Babkirk et al., 2015; DeCicco et al., 2012;Van Cauwenberge et al., 2017). These findings underscore the substantial inter-individual variability in the development of emotional regulation among young children, emphasising that their reappraisal abilities are still evolving. A significant shift in reappraisal capacity that modifies emotional processes indexed by LPP amplitudes may plausibly occur around the age of eight (DeCicco et al., 2014; Leventon & Bauer, 2016).

Furthermore, the LPP demonstrates developmental changes. The increased LPP observed in very young children in response to negative stimuli is a valid indicator of their growing cognitive appraisal maturation (Cheng et al., 2014; Hajcak et al., 2010). In other words, larger LPPs in young children, when viewing negative stimuli, indicate their growth in sustained appraisal and regulation. However, as children get older, their brain development becomes more efficient in emotion regulation, resulting in changes to the LPP pattern. A study of children and adolescents aged 7 to 19 found that emotional faces elicited larger LPPs than shapes, with LPP amplitudes decreasing with age for faces only (MacNamara et al., 2016). This decrease in LPP for emotional faces suggests improved efficiency and regulatory control in socio-emotional tasks as children mature (MacNamara et al., 2016). Hajcak and Dennis (2009) observed a reduction in LPP amplitude due to reappraisal in both males and females aged 7 to 10 but not in younger females aged 5 to 6. This discrepancy may indicate cognitive immaturity in this younger group (Dennis & Hajcak, 2009). Previous studies involving middle childhood children found that the LPP is sensitive to emotional stimuli in the middle temporal window (Hajcak & Dennis, 2009; Kujawa, Weinberg et al., 2012) but not in early or late windows (Hajcak & Dennis, 2009). Given that children's LPP tends to peak earlier than adults, its insensitivity in the later window suggests that emotional processing is still developing in middle childhood (Kujawa, Weinberg et al., 2012). Furthermore, research also noted a significant reduction in LPP amplitude over a two-year period among middle childhood children, particularly at occipital sites, indicating a developmental transition in emotional processing, characterised by a shift from reliance on brain regions linked to visual processing towards enhanced connectivity with frontal attention networks (Kujawa, Klein et al., 2012; Kujawa Weinberg et al., 2012).

Reappraisal intervention studies help to explain how LPP reductions in response to negative stimuli might be achieved in later childhood and how emotional learning experiences can influence this process. For instance, children (5-7 years old) exhibiting positive LPP difference scores—indicating that their LPPs were smaller during reappraisal compared to negative interpretation—demonstrated greater flexibility during emotional challenges (such as an increased propensity for alternative activities), both concurrently and two years later (Babkirk et al., 2015). Similarly, greater reductions in the LPP following reappraisal of negative story (negative story – reappraisal) were greater for children showing less anxiety (DeCicco et al., 2014). Moreover, children diagnosed with ADHD reported a lesser frequency of reappraisal use and could be differentiated from typically developing children based on LPP modulation (Van Cauwenberge et al., 2017).

As the improved appraisal process leads to a decrease in LPP in late childhood and beyond, the LPP studies involving emotionally arousing images are routinely employed to assess the LPP in relation to personality and emotional traits. For example, an overly intensified LPP in response to emotional imagery has been found to correlate with adolescents' personality traits of high extraversion (Speed et al., 2015) and elevated anxiety and depression in children aged between 6 and 11 (Chronaki et al., 2018). In comparison to their healthy counterparts, young people aged 7 to 19 years with current anxiety disorders display overly heightened LPP responses to angry and fearful faces, with the most pronounced effects observed in individuals with social anxiety disorder, as opposed to those with generalised anxiety disorder or separation anxiety disorder (Kujawa et al., 2015). In contrast, an increase in depressive symptoms has been found to correlate with significantly diminished LPP responses to angry faces among both healthy and anxious youth (Kujawa et al., 2015).

In addition to the commonly utilised paradigms involving emotional imagery or reappraisal, albeit limited in scope, the SJP has been employed to elicit the LPP following instances of social rejection or exclusion. For example, a recent investigation involving an adult demographic demonstrated that participants with low social anxiety exhibited distinctive LPP patterns, wherein the LPP induced by social acceptance was notably more pronounced than that triggered by social rejection (Gu et al., 2020). Conversely, this effect was deemed inconsequential for participants exhibiting high levels of social anxiety (Gu et al., 2020). In summary, individuals within the high social anxiety group displayed a lack of sensitivity in their emotional responses to both positive and negative social feedback. Collectively, the evidence we have reviewed shows that LPPs remain a valuable tool for examining children's emotional processes in their formative years.

2.4.4 Prediction bias: A real-time self-report measure within the ERP design

In addition to the ERP components examined in the preceding section, ERP studies utilising the SJP also investigate a crucial element within this paradigm: prediction bias. The 'prediction bias' in these studies is calculated as a relative percentage of the expectation of social acceptance. Previous studies with adult samples have consistently demonstrated an optimistic bias in predicting peer social evaluations (Dekkers et al., 2015; van der Molen et al., 2014; van der Molen et al., 2017; van der Veen et al., 2016). In contrast, the patterns of prediction bias among young children appear intricate. For instance, Gunther Moor and his colleagues (2014) studied children aged 8 to 14 using a social–non–social experimental design. They revealed that girls aged 8 to 14 consistently exhibited a permissive bias toward their male counterparts when anticipating social and non-social outcomes. In contrast, only the younger boys, specifically those aged eight to ten, demonstrated a permissive bias toward their female counterparts in predicting social feedback.

Additionally, a recent EEG study employing the SJP with healthy adolescents aged 12 to 17 examined prediction bias before, during, and after the SJP (Topel et al., 2021). They found no significant optimism bias before or during the task but observed a notable permissive recall bias, as participants reported receiving less positive feedback than was actually presented to them (Topel et al., 2021). Furthermore, this study found no significant age or gender differences in prediction biases throughout the task (Topel et al., 2021). Moreover, a SJP study involving participants aged 10 to 23 revealed that young adolescents predicted they would be liked less frequently than young adults, who, in contrast, overestimated peer acceptance (Rodman et al., 2017). In this context, young adults exhibited a more optimistic prediction bias compared to young adolescents, indicating "a developmental shift in explicit expectation of acceptance that troughs during adolescence and rises during the transition from adolescence to young adulthood" (Rodman et al., 2017, p. 50). Furthermore, this research uncovered age-related differences in how peer feedback influences self-perception (Rodman et al., 2017). Late adolescents and young adults reported an enhancement in self-views, while early adolescents demonstrated a decline in self-views when exposed to the same social feedback. The authors posit that younger adolescents may lack the self-protective biases (e.g., the optimism bias) that enable adults to maintain positive self-views following social rejection (Rodman et al., 2017).

In summary, adults show a prevailing optimism bias when anticipating social feedback. In contrast, findings from children and adolescents elucidate intricate patterns associated with prediction bias in social evaluations throughout childhood and adolescence.

2.4.5 Implications for the design of EEG/ERP study on social exclusion

As previously reviewed, ERP studies using the Cyberball or SJP paradigms have shown that these tasks offer a valuable experimental setting for understanding the neural correlates of social exclusion. Due to our particular emphasis on the dynamics of the Prediction-Feedback cycle as outlined in our social exclusion framework (see Section 2.3), the SJP paradigm is deemed a more suitable choice for this study. By utilising a child-appropriate, and ecologically enhanced version of SJP, this study intended to analyse the anticipation of social feedback (inclusion versus exclusion) as indicated by the SPN and the post-hoc feedback appraisal indexed by the FRN, P3, and LPP. Furthermore, this study examines the correlation between these real-time neural activities and self-reported distress and school belonging. A comprehensive discussion of the design is presented in the subsequent chapter, which focuses on the methodology.

Chapter 3 Methodology

3.1 Introduction

Based on the conceptual framework established in Chapter 2, this chapter presents the methodological design of the school-based multi-modal study conducted for this thesis. The study's design aimed to overcome the limitations and constraints of existing educational and neuroscientific approaches while capitalising on the advantages each approach offers. The chapter will elucidate how the designed school-based multi-modal approach explores the 'here-and-now' Prediction-Feedback cycle established among victims' embodied and embedded brains, peers' responses, and the social contexts in which social exclusion occurs. The empirical methods employed in this study were designed to address Research Question 2, as outlined below. All protocols and procedures described in this chapter have been approved by the Human Research Ethics Committee at the University of Sydney (Project No.2020/487).

Research Question 2: What neural dynamics are involved in predicting and appraising social exclusion perpetrated by unfamiliar peers, and how do real-time neural processes correlate with a child's self-reported responses regarding immediate distress from social exclusion, and their sense of school belonging?

3.2 Towards cross-modal research into the emotional dynamics of social exclusion

Kim et al. (2025) emphasise that though observation of overt behaviour or self-report paradigms is important, "they are prone to *street-light bias*—searching for something where it is easiest to look, but least likely to be found (Florio-Ruane, 2002). In education and developmental studies, such 'street-light bias' can result in underestimating children's abilities"

(p. 4). Traditional psychological studies on social exclusion are not free from this concern. As elaborated in Chapter 2, two primary traditions in the study of social exclusion, namely, the sociometric tradition and the behavioural tradition, are representatives of such an approach. The sociometric tradition conceptualises social exclusion as a consequence of peer group rejection, asserting that it is manifested through the 'self-reported sentiments' of peers (e.g., like versus dislike) (Ladd & Kochenderfer-Ladd, 2016). Conversely, the behavioural exclusion tradition emphasises peers' actions towards individual group members. In this tradition, social exclusion is assessed based on peers' active or passive exclusionary 'behaviours' (Ladd & Kochenderfer-Ladd, 2016). Although these methodologies provide significant insights and have improved our understanding of social exclusion within educational contexts (Ladd & Kochenderfer-Ladd, 2016), depending exclusively on self-reporting as the principal metric for assessing the subjective experience of social exclusion presents inherent methodological constraints. Furthermore, as discussed in Section 2.2, this line of inquiry presupposes linear causation among various contributing factors, primarily examining the correlation between social exclusion and a range of social, psychological, and academic outcomes. Due to these methodological constraints, traditional educational research concerning social exclusion is unable to explore the neurophysiological mechanisms that underlie the emotional dynamics experienced by victims. In reflection of these limitations, the conceptual framework of social exclusion offered in Section 2.3 incorporates the real-time neural mechanisms that underlie the anticipation of social exclusion and the post-hoc feedback appraisals. Also, the data collection design includes EEG/ERP recording as independent neurophysiological measures that can access emotional dynamics beyond the child's overt linguistic expressions (Kim et al., 2025).

EEG is a technique that allows for examining real-time neural activities when participants experience social exclusion (e.g., Tang et al., 2019; Van Noordt et al., 2015). The EEG/ERP technique enables investigations into the neural mechanisms that underpin cognitive, social, and emotional processing, particularly with children whose linguistic expressions of feeling and thoughts are limited. However, it should be noted that "neuroscientists usually limit their research to highly controlled settings and frame their questions at a level that deconstructs affective and social processing into components, given methodological and technological constraints" (Immordino-Yang & Gotlieb, 2017, p.346). Consequently, to maximise educational relevance and ecological validity, the design of this multi-modal study triangulates children's observable behaviours (e.g. overt expression of social prediction), self-report data (e.g., the immediate distress following social exclusion, sense of school belonging), and neurophysiological data collected from EEG/ERP recording. This cross-modal approach adeptly connects educational and neuroscience analyses, addressing the deficiencies in both domains concerning the investigation of social exclusion.

3.3 Operationalisation of the cross-modal approach and its advantages

The conceptual framework of social exclusion established for this study (see Figure 2.3.2.1) posits that social exclusion is a phenomenon emerging from a dynamic system of multiple contributing components, encompassing diverse peer relationships and social contexts such as normative and cultural values of schools where children belong. At the interface of the individual child and the given social context, recursive feedback loops are created when a child's brain constantly makes predictions about ongoing social interactions and then receives feedback that either confirms or rejects the preceding prediction (see Figure 2.3.2.2). The emotions experienced by victims of social exclusion are created in response to the brain's perceived outcomes, either the confirmation of predictions or error feedback. A cross-modal approach, incorporating EEG/ERP data collection, has been demonstrated to be capable of addressing these multiple levels, from neurophysiological to socio-behavioural, that the established conceptual model encompasses (see Fig 2.3.2.1). Figure 3.3.1 illustrates the multi-modal approach adopted in this study, integrating conventional educational research methods, such as questionnaires and interviews, with EEG/ERP techniques.

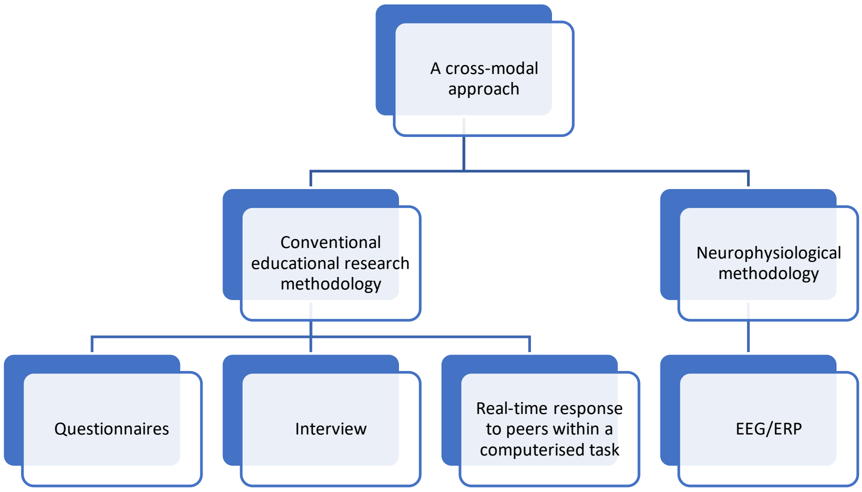


Figure 3.3.1 A cross-modal approach

Another significant premise of the present study is that human development, including emotional development, is influenced by multiple factors that evolve at their own pace and possess a distinct historical trajectory of change (Kim & Sankey, 2010). In the context of social exclusion, emotions manifest rapidly and self-organise as the embodied and socially, culturally embedded brain engages with Prediction-Feedback cycles. However, the predictions made by the brain are not arbitrary but rather represent the brain's best guesses based on long-term memories of the surrounding contexts, such as past memories of social inclusion/exclusion and norms of the school the child has been attending. Consequently, a child's immediate emotional experiences in the face of an exclusive incident may be constrained by relatively stable memories of the school context, such as a sense of belonging. The present multi-modal study design aims to encompass both transient (fast-changing) and stable (slow-changing) components within a social dynamic, with a focus on the socially and culturally embedded brain of the child. Figure 3.3.2 provides a detailed explanation of how these principles are operationalised in the methodology, along with further information on multidimensional data.

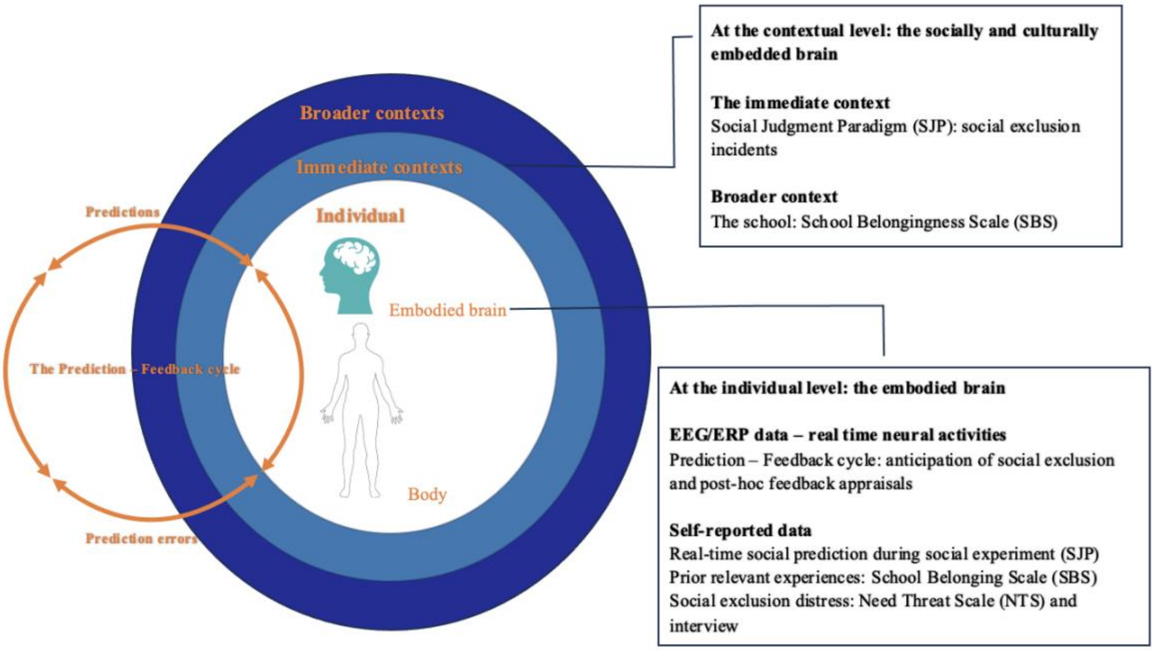


Figure 3.3.2 Data sources from multiple components within a social dynamic

Recognising the merits of psychological studies concerning 'exclusive behaviours', this study employed a well-established social exclusion experiment known as the SJP. During the modified version of this SJP experiment, participants experience an explicit form of social exclusion or inclusion, depending on whether they receive negative ('no') or positive ('yes') feedback from peers regarding their exclusion from or inclusion in a gaming team. It is important to emphasise that, in line with our conceptual framework, social exclusion or rejection fundamentally undermines the intrinsic human need to belong. Capturing the real-time anticipation and responses of participating children to ongoing experiences of inclusion or exclusion is of utmost importance, while also accounting for variability among different children. At an observable level, children were instructed to indicate their social predictions regarding whether another child would accept them as a game teammate by pressing either the ‘yes’ key or ‘no’ key. Simultaneously, the acquisition of EEG/ERP data facilitated capturing their real-time neural processes associated with this anticipatory phase, as well as the feedback appraisal process following either inclusion or exclusion. This experimental design allowed for a comprehensive analysis of the neural dynamics that both precede and follow instances of inclusion or exclusion. It also allowed for an exploration of the correlation between children’s social predictions of acceptance or rejection feedback and their anticipation of such feedback or subsequent feedback appraisals.

To the best of our knowledge, this study represents the first application of the SJP with children under eight. Previous neuroscientific inquiries utilising the SJP have predominantly focused on adult or older child samples (see Section 2.4.3). Notably, children below the age of eight have been significantly underrepresented in this area of research. By applying our conceptual model of social exclusion, we elucidated the Prediction - Feedback cycle by analysing neural activities during both the anticipatory and post-feedback phases while exploring the potential interrelations between social prediction and these real-time neural activities. Furthermore, the modifications implemented in the SJP (see Section 3.5.1) enabled us to engage younger children within an ecologically valid context, thereby facilitating an examination of the neural correlates associated with social exclusion in this demographic.

To examine the correlation between neurobiological processes captured from EEG/ERP data and subsequent distress following social exclusion by unfamiliar peers during the SJP experiment, we collected participants’ self-reported data immediately after the SJP experiment, during which simultaneous EEG/ERP recording was conducted. For this data, the Need Threat Scale (NTS; van Beest & Williams, 2006) was utilised alongside semi-structured interviews. The primary aim of the semi-structured interviews was to validate the self-reported data from the NTS. Furthermore, acknowledging the potential influences that participants' prior experiences of inclusion or exclusion at school might have on their real-time responses, we gathered children's ratings of their sense of school belonging by administering the School Belongingness Scale (SBS; Arslan & Duru, 2016). Participating children completed the SBS scale one week after the EEG data collection. The SBS comprises two subscales: the Social Exclusion Scale (SES) and the Social Acceptance Scale (SAS) (Arslan & Duru, 2016). Consequently, this self-reported data provided insights into students' real-life experiences concerning social inclusion and exclusion within their own schools.

By triangulating self-reported data from the NTS, SBS, and interviews with neurobiological EEG data, this study aimed to explore the interrelationship between different factors involved in the dynamics of social exclusion. For example, by probing the relationship between the SBS data and the EEG/ERP data, we examined how individual differences in past experiences of social exclusion within one's school relate to various neural processes identified in the SJP experiment. Furthermore, the design of the SJP experiment included both the anticipatory and post-exclusion phases, allowing us to examine correlations between children's social predictions and these anticipatory and subsequent feedback appraisal processes at the moment of social exclusion. All the self-report measures mentioned above, as well as the SJP, will be discussed in more detail later.

3.4 Participants

3.4.1 Rationale of the recruitment of participants

Despite the established understanding that social exclusion and bullying often occur among young primary school children (Wolke et al., 2001), there remains a limited comprehension of the neural correlates associated with social exclusion in this demographic. As detailed in

Section 2.4.3, prior EEG studies addressing social exclusion have predominantly employed the Cyberball and SJP. Notably, investigations using the Cyberball paradigm have primarily concentrated on individuals aged eight years and older (e.g., Baddam et al., 2016; Crowley et al., 2010; Sreekrishnan et al., 2014; Tang et al., 2019; Van Noordt et al., 2015). To mitigate this deficiency within the existing developmental literature and to offer the pedagogical insights requisite for timely intervention in social exclusion, the current study focuses on children aged six to eight years.

3.4.2 Sampling approaches

As discussed previously, according to our new conceptual framework on social exclusion, investigating the emotional dynamics associated with social exclusion among young primary school children requires the consideration of multiple components at both the individual and contextual levels. At the contextual level, in addition to the immediate context of the SJP experiment, the school is defined as the broader context relevant to this study due to its close association with our participants, who are school-aged children. Consequently, a 'cluster sampling' approach was employed to recruit schools. Although many schools were approached, only one confirmed its participation. After obtaining the principal's consent, the school administration office distributed invitations to students who met the eligibility criteria: healthy and typically developing children aged between 6 and 8 years. This 'cluster sampling' method also allowed the researcher to recruit the required number of participants within a limited research timeframe, particularly during the pandemic in 2022. Data was collected from students and their parents or guardians, who provided written informed consent. In addition, verbal consent was reaffirmed before EEG and self-report data collection. Participants were also informed of their right to withdraw from the study at any time.

The participating school is located in a western suburb of Sydney and serves typically developing primary and secondary students from families that reflect the community's demographics. This suburb includes areas that scored 1 or 2 on all four indices of the Socio-economic Indexes for Areas (SEIFA), as reported by the Australian Bureau of Statistics in 2016. These indices consist of the Index of Relative Socio-economic Disadvantage (IRSD), the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD), the Index of Economic Resources (IER), and the Index of Education and Occupation (IEO). These indices provide an insight into the average socio-economic characteristics of the individuals, families, and households living in the area. The scoring system operates on a scale of 1 to 5, with a score of 1 representing the most disadvantaged areas and a score of 5 representing the most advantaged areas.

3.4.3 Sample size

A total of 30 volunteers (16 females and 14 males), aged 6 to 8 years, and their caregivers were recruited from the participating school. Data from one participant (a female, 7.67 years old) was excluded from the EEG analyses due to an insufficient number of trials. As a result, 29 participants were included in the final EEG analyses. Regarding self-reported data, all participants (N = 30) completed the NTS and 29 completed the SBS. All participants were healthy volunteers with no documented history of neurological or psychiatric disorders.

The initial targeted sample size was thirty-six (36) students to achieve an effect size of $f = .25$ and a power of .95. This target was determined based on a power analysis conducted using G*Power version 3.1.9.7 for a 2 (Gender Group: Girls vs. Boys) by 4 (Prediction-Feedback Contingency Type: Yes/Yes, Yes/No, No/Yes, No/No) repeated measures analysis of variance

(ANOVA). However, despite the final number of participants in this study being 30 students, less than the recommended 36, further recruitment did not proceed due to strict restrictions from the ongoing COVID-19 pandemic, which limited visitor access to the school and students.

To address the limitations associated with the smaller sample size and to enhance statistical efficiency, as elaborated in Section 4.6.2, we employed a Mixed Effects Model (MEM) for data analysis rather than utilising the conventional ANOVA. In contrast to ANOVA, the MEM generally necessitates a reduced sample size. While mixed-effects models are increasingly employed in EEG research, established guidelines regarding sample size for this specific analytical methodology continue to evolve within the literature. Moreover, the integration of the Social Judgment Paradigm (SJP) with EEG and mixed-effects analysis signifies a notable innovation, and our sample size of 29 participants is consistent with similar research domains. Numerous EEG studies that employ the SJP typically involve 20 to 40 participants (e.g., Dekkers et al., 2015; Van der Molen et al., 2014; Van der Veen et al., 2014), and our mixed-effects approach affords enhanced statistical efficiency when compared to traditional analytical techniques.

3.5 Procedure

The data collection procedure consisted of two main components: a) the collection of EEG/ERP data, followed by the administration of the NTS and a debriefing session, and b) self-reports on participants' experiences of social exclusion in their schools. These two data collection components took place on separate days, with one week between the two components.

3.5.1 Social Exclusion Experiment – Social Judgment Paradigm (SJP)

As noted in Chapter 1, when developing the research design for this study, a methodological decision was taken to focus the EEG study exclusively on children experiencing exclusion from *unfamiliar* peers. This makes the study ethically viable (in not using real-life photographs of known children) and, importantly, it also enables the researcher to assess the extent of the positive impact a child's sense school belonging might have beyond the everyday familiarities of the school environment and known peers. As noted above, it is already well documented that a child's sense of school belonging has positive impacts on their academic achievements and their overall wellbeing at the school. But the question arises whether these positive impacts on achievement and wellbeing are replicated beyond the school, especially when experiencing exclusion from other similar-aged children who are not familiar?

To investigate social exclusion in ecologically valid but controlled social interactions that allow simultaneous EEG data collection, a modified SJP was used. In the widely used cover story in the SJP, participants were led to believe they would receive social feedback (e.g., being liked or disliked) from unknown peers based on first impressions; they were then asked to indicate whether the people whose photos appeared on the screen liked or disliked them. In contrast, in the present study, young children were informed that the social feedback they received from unfamiliar peers would indicate whether these peers would include or exclude them from an online gaming team. This manipulation effectively transformed the nature of peer social feedback into the dynamics of inclusion or exclusion associated with team participation. In addition, participants were led to believe that they would participate in a guessing game to identify who had invited them to join an online Minecraft team. These manipulations differed from those of the original SJP and were purposefully tailored for this study.

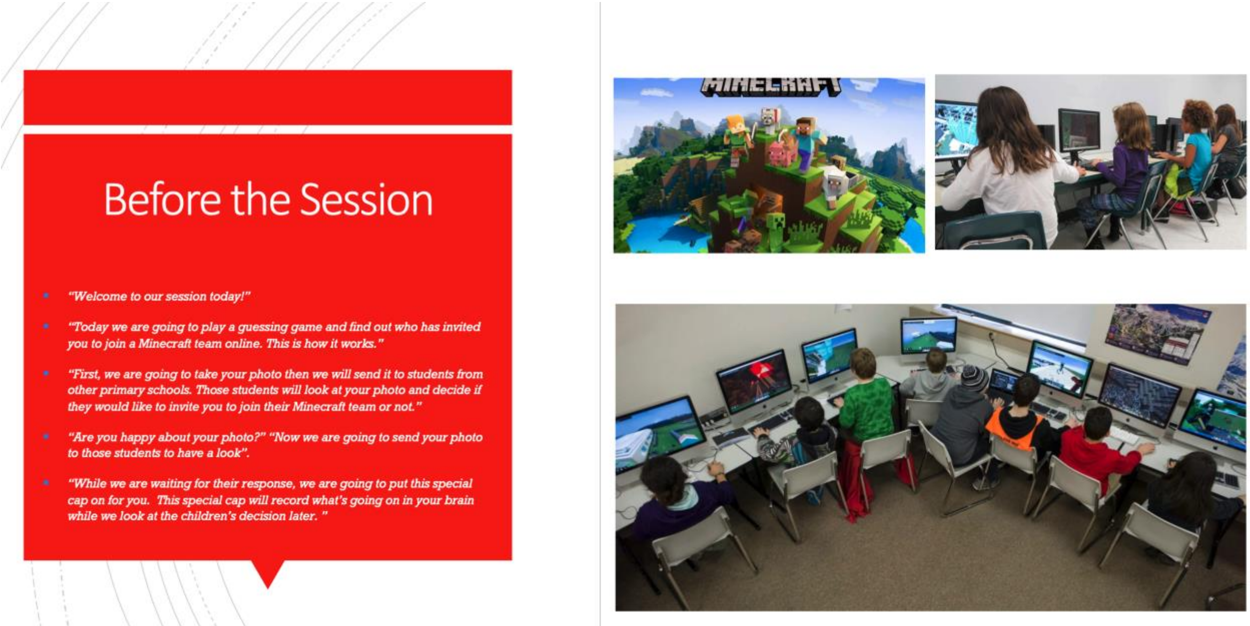


Figure 3.5.1.1 Cover story visual prompt

Table 3.5.1.1 EEG data collection procedure

	EEG data collection procedure
1	Welcome participants
2	Introduce cover story
3	Take participant photo
4	Pretend to send the photos to the panel members
5	Fit the EEG cap
6	Inform the participants the photo evaluation results are ready
7	Conduct EEG practice trials
8	Conduct formal EEG trials

The EEG data collection procedure is listed in Table 3.5.1.1 above. Upon arrival, all participants received a warm welcome and were thanked for participating in the experiment. They were then presented with a cover story designed to make them believe that peers from another school might invite them to join a Minecraft team after viewing their photos. Minecraft is a popular game familiar to young primary school children. To aid their understanding of the cover story, they were provided with a PowerPoint presentation containing the script and visual images of children playing Minecraft together (see Figure 3.5.1.1). Participants were then asked whether their photographs could be taken and shared with a group of peers from other primary schools. They were informed that their photos would be sent to the other children immediately and that those children would evaluate the photos to decide whether they would like to invite them to join a Minecraft team based on their first impressions. A researcher took photos of the participants, showed them the images, and asked if they were satisfied with the photos. Once the photos were approved, the researcher pretended to send the photo to the panel members using a phone in front of the participants, while other researchers prepared them for the EEG recording (e.g., measuring head size, fitting the EEG cap, and applying gel to the scalp). A few minutes later, the participants were informed that their photos had been successfully sent and that they would find out later whether the other children wanted to include them in their Minecraft team.

Once the participants were adequately prepared for the experiment, they were informed that the next step would be to check whether the children from other schools had given their feedback. The researcher conducted the social exclusion experiment using the SJP. Once the introductory page was displayed on the screen, the participants were informed that the other children had reviewed their photographs and submitted their responses. They were then instructed to participate in a guessing game to determine whether each child member of the peer panel had invited them to join the Minecraft team. Participants were told they would see the photographs of each member of this peer panel, displayed one at a time in the centre of the screen. Their task was to guess whether a particular peer had invited them to join the Minecraft team. It was made clear that their guesses would appear to the left of each photo, while the other child panel member's feedback would appear to the right. Participants would then discover the accuracy of their guesses. There was no apparent doubt among the participants about the cover story. They were not given any explicit instructions on what basis to judge the faces in order to avoid inducing systematic strategies for judging the faces and thus mimicking the integrity of real-life social interactions. This deceptive approach aimed to increase task salience and followed recommendations for ethically permissible research using deception (Wendler, 1996; Kim et al., 2025).

Continuous EEG was collected using a 32-channel ActiChamp (Brain Products) while participants engaged in the SJP experiment. The EEG was recorded at an A/D conversion rate of 1000Hz, referenced to the Cz channel. Correct cap application is critical to ensure an electrical connection to the scalp at each electrode. Given the young age of the participants, the 32-electrode cap (Brain Products Easy Cap) was chosen to minimise preparation and waiting time. Prior to recording, impedances and signal-to-noise ratio were checked, indicated by different colours of light emanating from each electrode. Impedance levels were also monitored on the Brain Vision Recorder page. Acceptable impedance levels were considered to be at or below 10k Ω before recording began. The preparation phase of the experiment took approximately 15 to 20 minutes.

A total of 130 photographs of peers were utilised. Participants commenced with 10 practice trials before completing six experimental blocks of 20 trials each. The 10 practice trial photos and the 120 (66 female and 54 male) experimental photos were sourced from the NIMH Child Emotional Faces Picture Set (NIMH-Chefs) (Egger et al., 2011) and the Child Affective Facial Expression set (CAFE) (LoBue & Thrasher, 2015), respectively. The CAFE set includes photographs of a racially and ethnically diverse group of children aged 2 to 8 years (M = 5.3 years; R = 2.7–8.7 years) posing with six emotional facial expressions and neutral faces (LoBue & Thrasher, 2015). Only the neutral faces of children of an age similar to the participants from the complete CAFE set were used in the experimental blocks. Previous research has shown that children are most accurate at recognising the faces of individuals within two years of their own age (Hills & Lewis, 2011). Approximately 96% of the photographs used in the experimental blocks were of children within two years of the participants' age. A sample of 100 untrained adults accurately identified the neutral facial expressions, achieving an accuracy rate of approximately 86%, indicating a high degree of variability in their accuracy scores (LoBue & Thrasher, 2015). In terms of internal consistency (reliability), the alpha score for neutral faces was calculated to be .37 ($\alpha = .37$) (LoBue & Thrasher, 2015). The CAFE set is recognised as a validated and reliable instrument. In addition, the CAFE set has been validated with a sample of children ($N = 58$, 28 males, 30 females; mean age = 4 years), demonstrating a strong predictive correlation between adult ratings and child ratings. This finding suggests that the adult validation of the CAFE set reported in LoBue and Thrasher's 2015 study may extend to child participants (LoBue et al., 2018).

Photographs of the peers were displayed on a 17-inch monitor [60 Hz refresh rate; visual angle (width/height) = (4.66∘× 6.05∘)] using E-prime 2.0 stimulus presentation software (Psychology Software Tools, Pittsburgh, PA, USA). The faces appeared against a white background and were presented once during the test session. Figure 3.5.1.2 shows a single trial procedure. Each trial began with a cue that lasted 4000 milliseconds and showed the neutral face of the peer. The cue remained on the screen until the end of each trial. During this 4000-millisecond interval, participants were instructed to indicate whether they believed the panel member included or excluded them from the Minecraft team by pressing one of two designated keys on the keyboard. In studies with adult samples, the cue interval was generally shorter, typically 3000 milliseconds (e.g., Van der Molen et al., 2014; Van der Molen et al., 2017; Van der Veen et al., 2014) or between 2400 and 3400 milliseconds (e.g., Dekkers et al.,2015). Following our pilot study, we extended this interval to give our younger participants more time to respond. The order of the keys (left or right) corresponding to acceptance ('yes') or rejection ('no') was counterbalanced across participants.

Trials in which participants responded too slowly (i.e., after 4000 milliseconds from cue onset) were excluded from the analysis. Following the participants' social prediction, their responses ('yes' or 'no') were immediately displayed on the left side of the photograph. Following a predetermined interval of 3000 milliseconds (i.e., the anticipation period), peer feedback was presented for 2000 milliseconds on the right side of the photograph, indicating either inclusion ('yes') or exclusion ('no'). The feedback in this paradigm was generated by a computer in a randomised order, with 50% of trials resulting in rejections. A fixation cross was displayed in the centre of the screen between trials, with a jitter duration of between 500 and 1500 milliseconds (see Figure 3.5.1.2). Responses not recorded within the 4000 milliseconds timeframe were followed by a 'Too Slow' and 'No response detected' message, indicating the end of the trial. This design produced the following prediction-feedback congruency types: expected inclusion (YY), unexpected inclusion (NY), expected exclusion (NN), and unexpected exclusion (YN).

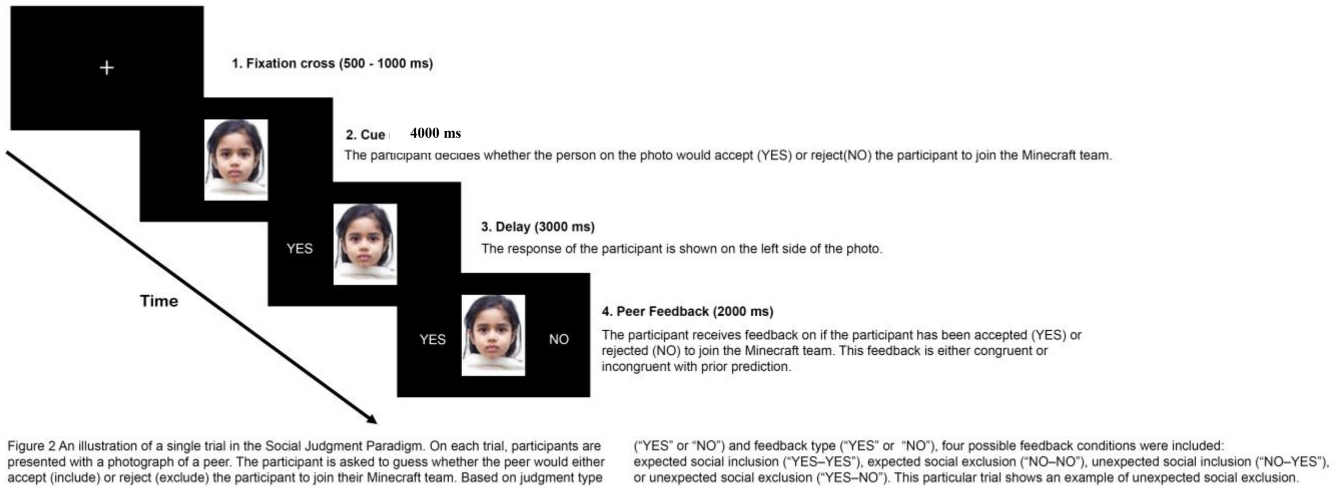


Figure 3.5.1.2 Schematic overview of a single trial sequence of the SJP

To minimise movement during the EEG recording, participants were instructed to use their left and right index fingers to press the keys corresponding to either a 'yes' or 'no' response. They were also advised not to make large movements or engage in conversation. Instead, participants were encouraged to move and speak at designated intervals. After each break, participants would indicate their readiness for the next block. A footrest was placed beneath the participants' feet to ensure their comfort and to prevent their legs and feet from shifting during the experiment. Additionally, one of the researchers sat next to the participants throughout the EEG data collection to remind them to minimise large movements with a brief, gentle touch on the affected body parts.

3.5.2 Self-reported measurement

The current study used a range of self-reported metrics in combination with the EEG data, as demonstrated in Table 3.5.2.1. None of the participants exhibited any scepticism about the cover story.

Table 3.5.2.1 Self-reported measurements

Data set	Participants	Instruments/ Tasks	Time
Social exclusion distress	Children	NTS	Straight after the EEG collection
Emotional experience during the SJP	Children	Interview	Straight after the administration of the NTS
Sense of school belonging	Children	SBS	Around one week after the EEG collection session
Demographics information	Parents	Demographics questionnaire	After consent received

Need Threat Scale (NTS)

Immediately following the EEG session, a revised NTS (van Beest & Williams, 2006) was administered to assess the distress associated with social exclusion experienced during the SJP experiment (see Appendix B-2). The original NTS consists of 20 items designed initially for the Cyberball task (van Beest & Williams, 2006). The language was carefully refined, and unnecessary items were removed to better suit our young participants and the experimental design. As a result, the revised NTS used in the present study consists of 17 items. The NTS (van Beest & Williams, 2006) is recognised as a reliable and valid measure of distress associated with social exclusion and has been used extensively in previous research (e.g., Baddam et al., 2016; Crowley et al., 2010; Tang et al., 2019; Van Noordt et al., 2015). This instrument assesses feelings of distress or threat across four dimensions of basic psychological needs: belongingness ('I felt like I didn't fit in with the others''), self-esteem ('I felt unsure of myself'), meaningful existence ('I felt invisible'), and control ('I felt powerful': reverse-scored). Responses are rated on a five-point scale ranging from 1 ('Not at all') to 5 ('Extremely') (Baddam et al., 2016). Increased scores on the NTS indicate increased distress.

A researcher, who is also a primary school teacher, sat with the participants to explain how to complete the scale and the meaning of each answer choice. Once the participants indicated that they understood the procedure, the researcher read each question aloud and marked their chosen answer on the paper copy of the scale. The researcher provided additional clarification as needed.

Following the administration of the NTS, a brief interview was conducted. The main purpose of this interview was to allow participants to verbally express their feelings about their experiences of exclusion during the experiment. The interviews were video recorded with the participants' permission. The recordings were used to corroborate the data from the NTS questionnaire, so we did not analyse and report on them in Chapter 4.

School Belongingness Scale (SBS)

Approximately one week later, participants' subjective perceptions of belonging in their respective schools were assessed outside the EEG laboratory using the SBS (Arslan & Duru, 2016) (see Appendix B-4). The SBS is a self-report instrument consisting of ten items using a 4-point Likert-type scale (1 = almost never to 4 = almost always, e.g., 'I feel excluded in this school' and 'I feel part of this school'). This scale consists of two subscales: the Social Exclusion Scale (SES) and the Social Acceptance Scale (SAS), each containing five items. In a previous study with adolescents aged 11 to 19 years, the SES was found to have robust internal reliability (α = .76) (Arslan, 2018). Overall, the SBS is a structurally reliable and valid instrument (Arslan & Duru, 2016). Similar to the administration of the NTS, a researcher accompanied the participants, explaining the questions and corresponding answers before encouraging them to respond and providing further clarification as necessary. Upon completion of the SBS, the participants were verbally debriefed about the true purpose of the study.

Parent survey

Demographic information was collected from parents and caregivers using a simple demographic questionnaire (see Appendix B-1). Parents and caregivers were sent an invitation link with their child's unique participant number to complete the questionnaire online. To protect privacy, only the participant number of the enrolled child was required to complete the form. After the demographic questionnaire, a debriefing statement automatically appeared on the screen to clarify the true purpose of the study, and parents were allowed to withdraw from the study if they wished.

3.6 Ethical Considerations

The study was formally approved by the Human Research Ethics Committee (HREC) at the University of Sydney. The researchers approached potential participating schools and explained the purpose and content of the study. After obtaining permission from the school principal, the recruitment advertisement was distributed to families through the schools. An Invitation Letter and Participants Information Statements (Appendix A-2 to A-5) were made available through the administration office of the school. Consent forms were obtained from both child participants and their parents or guardians (Appendices A-6). It is important to emphasise that no coercion was used during the recruitment process, and participants were fully informed of their right to withdraw from the study at any time. Participants were fully informed of the data collection procedures involved in the study. This study contained elements of deception, as participating children were led to believe that the primary objective was to examine whether the children from other schools chose them to play an online game based on first impression. After completing the SBS, participating children were debriefed about the true purpose of the study. A researcher verbally explained to the participating children that the research focused on their emotional reactions to being rejected from joining the Minecraft team. A debrief letter was sent to their parents or caregivers via REDCap (Appendices A-7). Participants received a certificate of participation upon completion of the EEG data collection.

Chapter 4 Results

4.1 Introduction

As introduced in Chapter 1, this study aims to address the following three research questions.

Research Question 1: What emotional experiences do young primary school children, aged 6 to 8 years, encounter when faced with social exclusion from other children, and how might these experiences influence their well-being?

Research Question 2: What neural dynamics are involved in predicting and appraising social exclusion perpetrated by unfamiliar peers, and how do real-time neural processes correlate with a child's self-reported responses regarding immediate distress from social exclusion, and their sense of school belonging?

Research Question 3: What insights can be gained from the findings of multimodal data regarding the most effective strategies to assist primary school children in coping with the felt social and emotional consequences of social exclusion?

The literature review provided in Section 2.2 has yielded significant insights into Research Question 1. The self-reported data gathered from our study, which includes the NTS and the SBS, will offer further information pertinent to addressing Research Question 1. Importantly, our analysis of the correlations between the self-reported data and the ERP components will deliver additional insights essential to this question.

In addressing Research Question 2, we have selected the SJP for our social exclusion experiment, during which EEG/ERP data were collected. As previously articulated, the SJP facilitates examining neural processes during two distinct phases: the anticipation of social feedback and the subsequent feedback appraisal. As reviewed in Section 2.4, ERPs, which involve extracting time-locked neural responses to specific events from the raw EEG data, have been utilised in numerous recent studies to elucidate the neural dynamics underlying these two phases of the SJP.

Based on our literature review and the new conceptual framework on social exclusion (see Section 2.3), we extracted ERP components from both phases to address Research Question 2. More specifically, the SPN was extracted from the EEG data 200 milliseconds prior to the feedback onset, while feedback-related ERPs, including the FRN, P3/P300, and LPPs, were extracted following the feedback onset (see Figure 4.1.1). The SPN enabled us to analyse the anticipation of social feedback, whereas all feedback-related ERPs facilitated the analysis of post-hoc feedback appraisal. Furthermore, as discussed in Chapter 3, this study adopted a cross-modal approach, collecting multidimensional data. Another significant aspect of the data analysis involves examining the correlations between these ERP components and the self-reported data (e.g., social prediction, NTS and SBS). Therefore, these ERPs, in conjunction with self-reported measures, allowed us to effectively address Research Question 2. In the remainder of this chapter, we will present the findings derived from each ERP and the self-reported data. Research Question 3 will be addressed in Chapter 5.

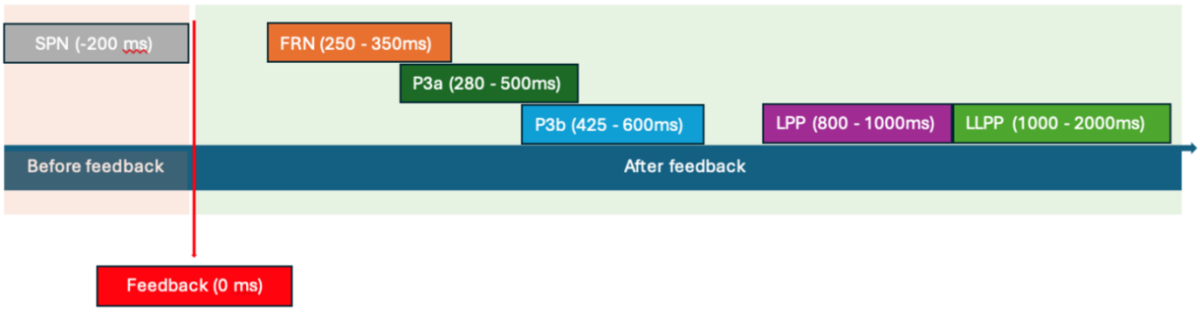


Figure 4.1.1 ERPs and their time windows

4.2 The central focus of the data analysis

As previously mentioned, in the current study, two principal data sources—EEG/ERP and self-reported data—were employed. Regarding the EEG data, as illustrated in Figure 4.1.1, multiple ERP components were extracted to investigate the neural dynamics that occur both prior to and following the receipt of peer feedback. The neural processes between the child's own prediction of peer acceptance or rejection and the subsequent peer feedback reflect the anticipatory process while awaiting peer acceptance or rejection. During this anticipatory phase, SPN was identified, as noted in the literature (Kotani et al., 2001; Ohgami et al., 2004; Van der Molen et al., 2014). In the subsequent analysis, we examined the differences in SPN across two conditions: when a child expects that the peer will accept him or her (Yes Prediction) and when a child anticipates rejection from the peer (No Prediction). The neural processes following the receipt of peer feedback were indexed by feedback-related ERPs, which encompass FRN, P3a, P3b, LPP, and LLPP. These ERP components were analysed to determine amplitude variations across different conditions based on Prediction Valence, Feedback Valence, and four congruent and incongruent conditions: expected acceptance (Yes Prediction/Yes Feedback), unexpected rejection (Yes Prediction/No Feedback), unexpected acceptance (No Prediction/Yes Feedback), and expected rejection (No Prediction/No Feedback). By investigating the amplitude differences in ERPs among these conditions, we aimed to gain insight into the victims' experiences, exploring the neural mechanisms involved when they encounter social acceptance or rejection, whether anticipated or unanticipated. Furthermore, an additional data source utilised in our study was self-reported data. By analysing the relationship between EEG/ERP and self-report data collected through the NTS and SBS, we endeavoured to triangulate our findings, juxtaposing the victims' subjective experiences of social exclusion, as highlighted by self-report data sources, with EEG/ERP data that reflect neural processes operating with minimal voluntary control from participants.

4.3 Participants

Participants were recruited from an independent primary school in Western Sydney. Detailed information on the socio-economic backgrounds of the school was presented in Chapter 3. This sample was gender-balanced, with 16 females (53.3%) and 14 males (46.7%). Some families did not provide their participating child's age, although they did consent; therefore, 23 out of 30 participants were included in the age analysis. The participants' ages ranged from 6.17 to 8.92 years, with a mean age of 7.46 years and a standard deviation of .78. These results offer an overview of the age distribution among the participants, indicating a relatively narrow range with a central tendency around 7.46 years.

4.4 Student's self-reported social exclusion experiences and sense of school belongingness

4.4.1 Need Threat Scale (NTS)

All participants completed the NTS (N=30) *immediately after* the social exclusion experiment to report ostracism distress experienced during the experiment. Descriptive statistics were calculated to summarise the distribution of NTS scores in the sample. Most participants did not report feeling distressed during the social exclusion experiment because their NTS scores were lower than 51, which is the score a participant would obtain if she/he selected 'neutral' for all questions. In other words, if a participant's NTS score was less than 51, this participant did not feel too distressed during the experiment. As shown in Table 4.4.1.1, only 3 participants obtained a score that was slightly over 51, while only 2 participants' scores were over 60. These results were consistent with our expectations, given that the exclusion scenario in the experiment was similar to what often happens in online games and classrooms. The exclusion in the experiment was less serious than what children experience in real life because those who excluded them were not their real friends; in other words, they were not significant people. More detailed descriptive statistics for NTS are presented in Table 4.4.2.2. The mean NTS score for the entire sample was 42.6 (M = 42.6, SD = 8.892), far lower than 51 (the neutral score).

Table 4.4.1.1 Frequency table of NTS score distribution in the sample (N = 30)

NTS score	N	%
31.0	1	3.3%
32.0	2	6.7%
33.0	3	10.0%
34.0	1	3.3%
35.0	1	3.3%
37.0	2	6.7%
38.0	2	6.7%
39.0	1	3.3%
40.0	1	3.3%
42.0	2	6.7%
43.0	1	3.3%
44.0	2	6.7%
46.0	1	3.3%
47.0	4	13.3%
49.0	1	3.3%
52.0	1	3.3%
54.0	2	6.7%
63.0	1	3.3%
65.0	1	3.3%

Nevertheless, there was a range of individual differences in perceived distress levels, with a 34-point gap between the highest and lowest scores. To examine gender differences, an independent samples t-test was performed. No significant gender difference in distress was *found,* t (28) = -.752, p = .459 (see Figure 4.4.1.1).

Figure 4.4.1.1 NTS gender comparison

4.4.2 School Belongingness Scale (SBS)

Twenty-nine out of thirty participants completed the SBS to report their sense of belonging in daily school life. The SBS was administered about a week after the EEG data collection at a different venue within the school, which was not involved in the experiment. This time gap and venue change enabled us to measure the students' daily experiences of school belonging rather than their experiences during the SJP experiment. Descriptive statistics were calculated to summarise the distribution of SBS scores in the sample. The neutral score for SBS was 25, corresponding to a score in which participants selected 'neutral' for all questions on the questionnaire. In other words, if a participant's SBS score was below 25, it indicated that they do not experience a sense of belonging during their daily school life. As shown in Table 4.4.2.1, approximately 89.8% of participants who completed the scale felt a sense of belonging at their school with an SBS score above 25 (the neutral score). In contrast, 6.6% of participants rated their sense of belonging to the school as slightly negative, while 3.3% felt neutral. Table 4.4.2.2 provides more detailed descriptive statistics for the SBS. The mean SBS score for the whole sample was 33.155 ($M = 33.155$, $SD = 4.402$), which exceeds 25 (the neutral score). A higher SBS score reflects a stronger sense of belonging within the school context.

Table 4.4.2.1 Frequency table of SBS score distribution in the sample (N = 29)

SBS score	N	%
24	1	3.3%
24.5	1	3.3%
25	1	3.3%
29	4	13.3%
30	2	6.7%
31	1	3.3%
33	3	10%
34	4	13.3%
35	2	6.7%
36	3	10%
37	1	3.3%
38	4	13.3%
39	1	3.3%
40	1	3.3%
Missing	1	3.3%

Table 4.4.2.2 NTS and SBS descriptive statistics

		NTS	SBS
N	Valid	30	29
	Missing	0	1
Mean		42.600	33.155
Median		42	34
Mode		47	29
Std. Deviation		8.893	4.402
Variance		79.076	19.377
Skewness		.835	-.540
Std. Error of Skewness		.427	.434
Minimum		31	24
Maximum		65	40

An independent sample t-test was conducted to examine gender differences. No significant differences in school belongingness were found between genders, t (27) = 1.240, p = .226 (see Figure 4.4.2.1).

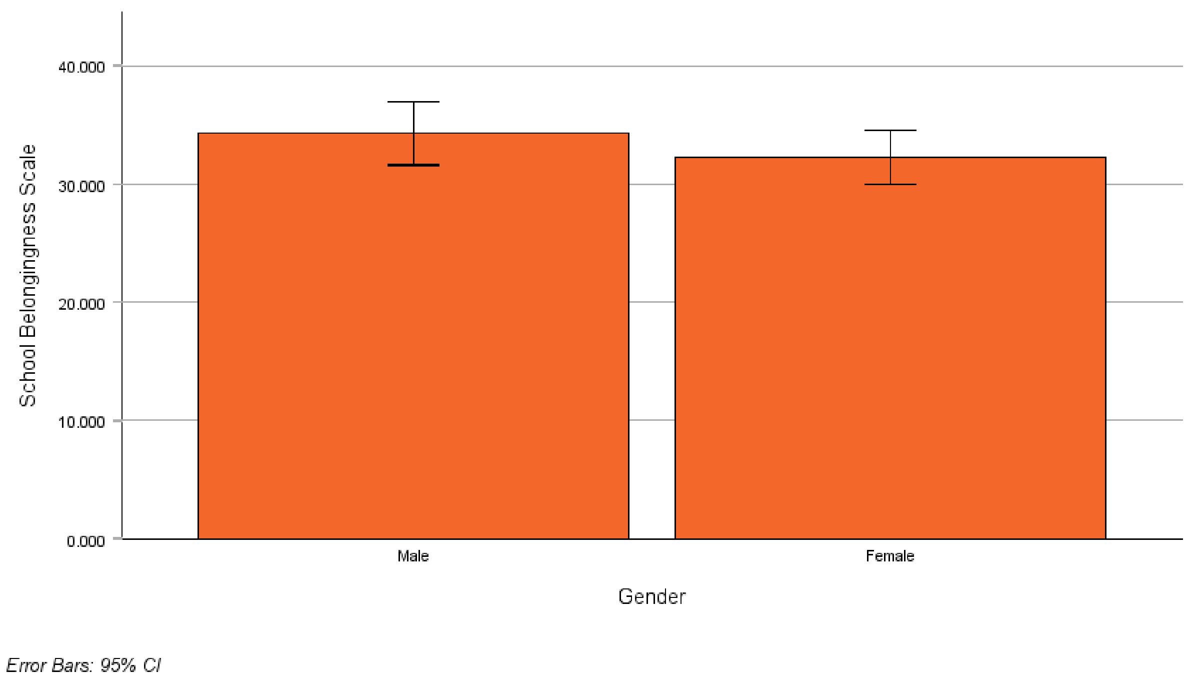


Figure 4.4.2.1 SBS gender comparison

4.4.3 Correlation between NTS and SBS

It was hypothesised that the greater the sense of belonging participants felt in their school, the less ostracism they experienced during the social exclusion experiment. A higher NTS score indicates more ostracism, while a higher SBS score reflects greater school belongingness. Therefore, we hypothesise that these two variables should be *negatively* correlated.

Before examining the correlation between NTS and SBS, we conducted outlier and influential point diagnostics using distances (e.g., Cook's), residuals (e.g., studentised deleted residuals), and influence (e.g., DF beta and DF fit) statistics in SPSS. Two influential outliers (participants 060706 and 061602) were diagnosed and excluded. Based on the outlier diagnosis outcomes for each model, different participants were excluded when building models for further analysis, as reported later.

A Pearson correlation analysis was conducted to assess the relationship between the social exclusion distress participants felt during the exclusion experiment, as measured by NTS, and their sense of school belonging during their daily school life, as reflected by the SBS measurement. The results confirmed a statistically significant negative correlation between these two variables: r (25) = -.453, p =.018. Hence, our hypothesis was supported. This shows that the more belongingness the participants felt in their school, the less social exclusion distress they felt in the social exclusion experiment.

After confirming a significant negative correlation between the SBS and NTS using a Pearson correlation test, a bivariate regression was conducted to examine how well school belongingness could predict the level of social exclusion distress experienced during the exclusion experiment. Below, a scatterplot (Figure 4.4.3.1) illustrates a negative linear relationship between belongingness and ostracism despite the time gap (1 week) between the two data collections. The Standard Residual ranged from -1.959 to 2.213, between -3.29 and +3.29, indicating that no bivariate outliers were present. The error distribution was normal. The effect size analysis showed that 20.5% of the variability in ostracism experienced by participants during the exclusion experiment was accounted for by their level of belongingness in daily school life. Overall, the model demonstrated a good fit for the data.

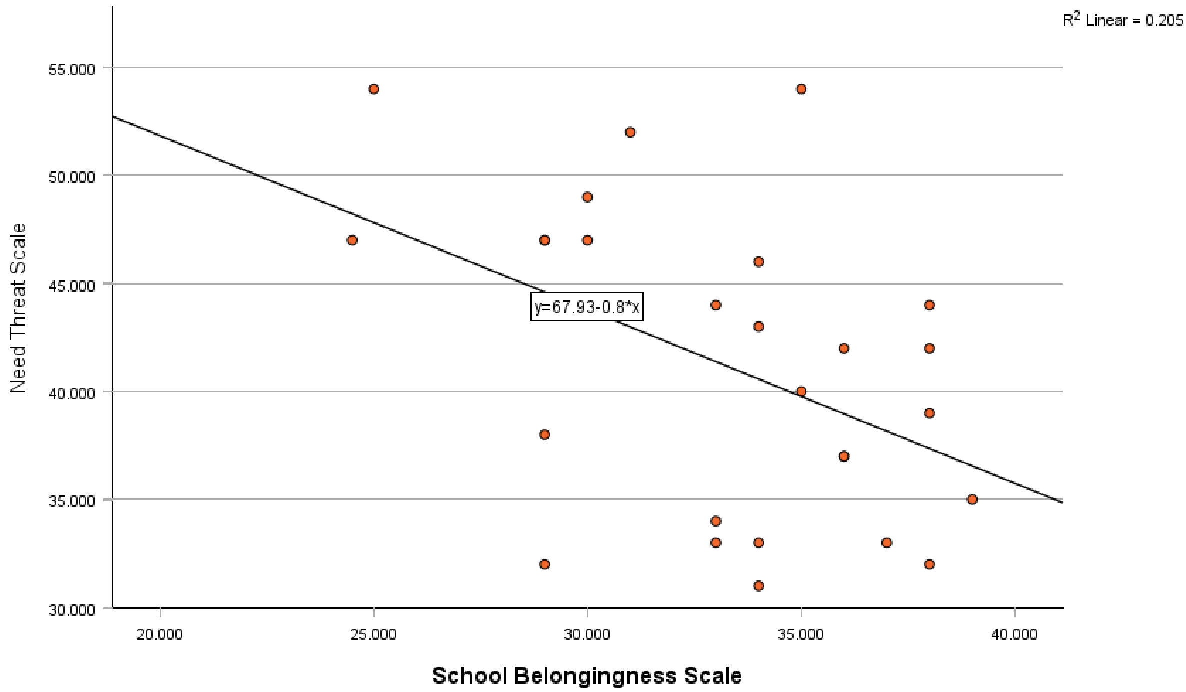


Figure 4.4.3.1 NTS and SBS correlation scatterplot (N = 27)

As shown in Table 4.4.3.1, there was robust evidence that the NTS scores were associated with the SBS scores (p =.018). When other factors remained constant, a 1-point increase in the SBS score was associated with a decrease in the NTS score between -1.457 and -.152, with a 95% confidence interval. The standardised coefficient (−.453) showed the strength and direction of the relationship in standard deviation units. This value indicated a moderate negative relationship between the SBS and NTS scores.

Table 4.4.3.1 Coefficients between the SBS and NTS (N = 27)

	Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
	B	Std. Error	Beta	*t*	*Sig.*	Lower Bound	Upper Bound
(Constant)	67.928	10.607		6.404	<.001	46.083	89.772
SBS	-.805	.317	-.453	-2.539	.018	-1.457	-.152

In conclusion, there was a statistically significant negative relationship between the SBS and NTS scores. As school belongingness increases, the perceived social exclusion distress decreases. The model indicated that higher levels of perceived belongingness to one's own school were associated with lower levels of perceived distress when facing exclusion from unknown peers. This relationship was statistically significant, and the confidence interval indicated that this finding was reliable.

4.5 Prediction pattern

4.5.1 Acceptance and Rejection Prediction

A *prediction bias* score was calculated to examine whether participants tended to anticipate more acceptance than rejection from peers introduced in the experiment (Van der Molen et al., 2014). This prediction bias score was derived by dividing the number of acceptance predictions by the total number of predictions. This bias score reflects either an optimism bias (>0.5) or a pessimism bias (<0.5). One participant (060302) was excluded from all analyses involving prediction bias due to a limited number of trials. Another participant (061602) was excluded as an extreme outlier after an outlier diagnosis using distances (e.g., Cook's), residuals (e.g., studentised deleted residuals), and influence (e.g., DF beta and DF fit) statistics in SPSS. A total of 28 participants were included in all analyses involving prediction bias.

The average bias score was .549 (N = 28, SD = .103) (See Table 4.5.1.1). On average, participants expected acceptance feedback (M = 63.321, SD = 12.89) more often than rejection feedback (M = 51.75, SD = 11.648), indicating that participants exhibited an optimism bias by anticipating more social acceptance feedback. A one-sample t-test confirmed that the average bias score significantly differed from 0.5, t (27) = 2.512, p = .018, SE = .020, SD = .103, $|M_{diff}|$ = .049, 95% CI [.009, .089], indicating an optimism bias in the sample. However, the effect size, as measured by Cohen's d (d = .103), indicated a very small effect size. This implies that the difference between the average bias score of the sample and 0.5 was not substantial.

Table 4.5.1.1 Prediction Descriptive Statistics (N = 28)

	N	Min.	Max.	Mean	SE	SD	Variance
Yes Prediction	28	25	91	63.321	2.436	12.890	166.152
No Prediction	28	29	82	51.750	2.201	11.648	135.676
Bias Score	28	.281	.758	.549	.0195	.103	.011

An Independent sample t-test was conducted to check for any gender differences in prediction bias. Both boys (N = 14, M = .578, SD = .116, SE = .031) and girls (N = 14, M =.520, SD = .084, SE = .022) displayed an optimism bias with a mean bias score above 0.5. However, the difference between the genders was not statistically significant, t (26) = 1.520, p = .141, SE = .038, $|M_{diff}|$ = .058, 95% CI [-.020, .136]. Additionally, the effect size, measured by Cohen's d (d = .101), suggested a very small effect size.

4.5.2 Correlation between prediction and self-report measurements

Pearson's correlation analysis was performed to evaluate the relationship between SBS and prediction bias scores. We expected a positive correlation between these two variables, meaning that the more belonging participants felt, the more optimistic their predictions for acceptance in the experiment were. However, this relationship was not statistically significant: *r* (25) = .211, *p* = .982 (See Figure 4.5.2.1).

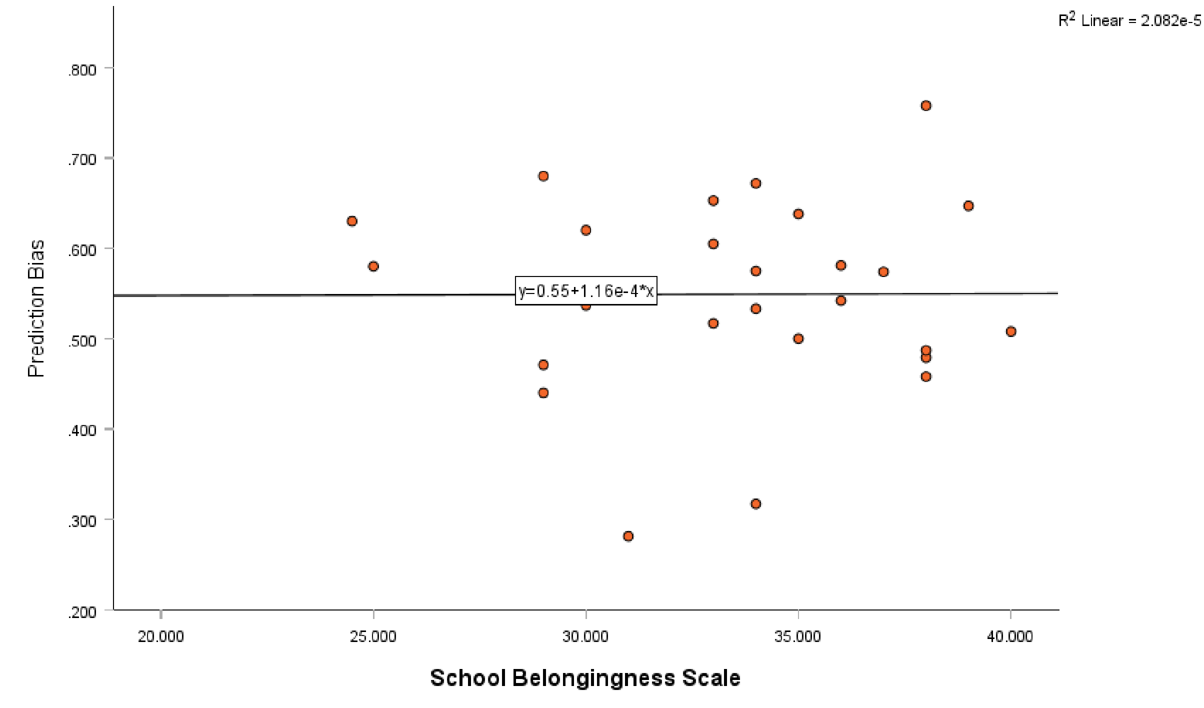


Figure 4.5.2.1 Correlation between the bias score and the school belongingness

As shown in Table 4.5.2.1, there was no evidence that the SBS scores were associated with the prediction bias (*p*=.982).

Table 4.5.2.1 Coefficients between SBS and prediction bias (N=27)

	Unstandardized B	Coefficients Std. Error	Standardized Coefficients Beta	*t*	*Sig.*
(Constant)	.545	.171		3.198	.004
SBS	.000	.005	.005	.023	.982

In conclusion, there was no significant correlation between SBS scores and prediction bias. We also conducted Pearson's correlation to assess the relationship between NTS and prediction bias scores. We expected a negative correlation between these two variables, meaning that the more exclusion distress the students felt during the social exclusion experiment, the more pessimistic their predictions for acceptance became. However, this relationship was insignificant: r (26) = -.163, p = .407 (See Figure 4.5.2.2).

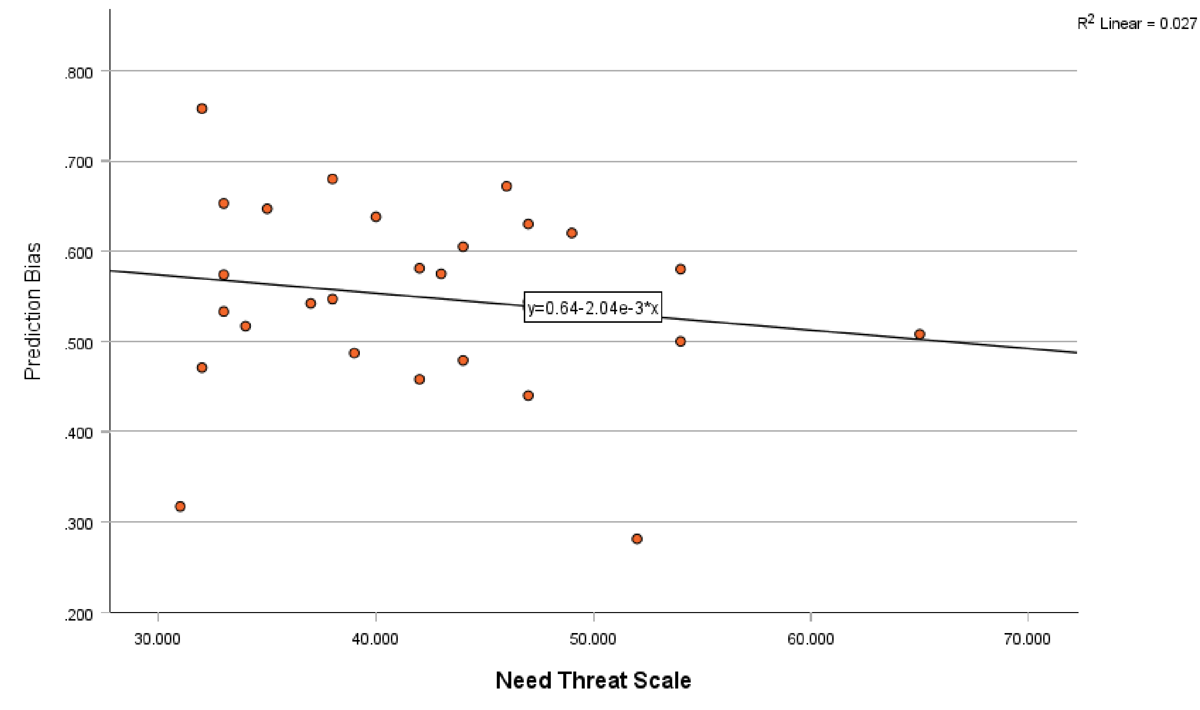


Figure 4.5.2.2 Correlation between the bias score and the exclusion distress

As shown in Table 4.5.2.2, there was no compelling evidence that the NTS scores were associated with prediction bias (p=.407). The standardised coefficient (-.002) indicated a very small negative relationship between the NTS and bias scores. Although insignificant, the relationship between the NTS and prediction bias was stronger than that between the SBS and prediction bias.

Table 4.5.2.2 Coefficients between NTS and prediction bias (N=28)

	Unstandardized B	Coefficients Std. Error	Standardized Coefficients Beta	*t*	*Sig.*
(Constant)	.635	.104		6.113	<.001
NTS	-.002	.002	-.163	-.843	.407

In conclusion, neither of the correlations between the bias score and the NTS or SBS scores achieved statistical significance.

4.6 EEG

4.6.1 EEG pre-processing

The EEG data were offline pre-processed using the Brain Vision Analyzer (Version 2.1.1) (Brain Products). First, the data were down-sampled to 256Hz and then re-referenced to the average of all electrodes. Following the re-referencing, EEG data were filtered using an IIR filter of 0.1-30Hz. Gratton-Coles correction was performed to correct for artifacts caused by eye movements, particularly blinks. Artifact rejection was conducted using a -120 μV to 120 μV threshold in addition to visual inspection and rejection. Following the basic raw data pre-processing, data were segmented to obtain separate waveforms for SPN and the Feedback Related Potentials (FRPs) for each congruency type (YY, YN, NY and NN). For the SPN, a total of 3500 milliseconds segments were created to isolate the SPN, including a 200-millisecond post-feedback-stimulus interval. For the FRPs, including FRN, P3a, P3b, LPP and LLPP, epochs were created with the baseline 200 milliseconds before the onset of the feedback stimulus until 2,000 milliseconds afterwards. The epochs of each congruency type were averaged and then were baseline corrected. A grand average for different Prediction Valences, Feedback Valences, and congruency types was computed by combining individual participants' corrected averages. Only participants whose data had at least ten artifact-free trials for each congruency type were included in the grand averaging and following statistical analysis (total N = 29).

4.6.2 EEG statistical analysis – Mixed Effects Models (MEM)

In this study, we employed Mixed Effects Models (MEM) analysis to investigate differences in EEG/ERP data across different groups (e.g. gender) and conditions (e.g. types of prediction and feedback) while exploring interactions between variables. This decision was made by admitting the growing recognition of constraints from repeated measures analysis.

> In neuroscience research, longitudinal data are often analysed using analysis of variance (ANOVA) and multivariate analysis of variance (MANOVA) for repeated measures (rmANOVA/rmMANOVA). However, these analyses have special requirements: The variances of the differences between all possible pairs of within-subject conditions (i.e., levels of the independent variable) must be equal. They are also limited to fixed repeated time intervals and are sensitive to missing data. (Melo et al., 2022, p. 6089)

In contrast, MEM offers several advantages. It enables researchers to avoid violating the assumption of statistical independence of observations, identify important relationships in the data that traditional ANOVA models might overlook, and provide precise estimates of effect size (Wainwright et al., 2007).

Additionally, MEM provides a more effective approach for handling missing data. In repeated measures ANOVA methods, participants with missing data are excluded from the analysis, which can significantly reduce statistical power or require the inclusion of additional participants (Wainwright et al., 2007). The flexibility of the MEM is particularly advantageous in studies like the one described here, where a small sample size might compromise the ANOVA (Wainwright et al., 2007). Indeed, Yu et al. (2022) suggested that the appropriate use of MEM would lead to “data analyses with greater validity and higher reproducibility” in neuroscience research (p. 21). Therefore, in this study, instead of using the traditionally employed Repeated Measures ANOVA for the statistical analysis of repeated measure EEG data, a MEM approach was utilised. A separate mixed-effects model was constructed for each ERP component.

As detailed in Table 4.6.2.1 below, the corresponding ERP amplitude was set as the dependent variable in each mixed-effects model for individual ERP components, with participant number defined as a random factor. The SPN, the only ERP component occurring before the feedback, had five predictors: gender, Prediction Valence, electrodes, SBS score, and NTS score. The categorical predictors, such as gender, Prediction Valence, and electrodes, were defined as fixed factors, while the other predictors, which were continuous variables, such as the SBS and NTS scores, were treated as covariates. For all FRPs that occurred after the feedback, including FRN, P3a, P3b, LPP, and LLPP, an additional predictor, feedback, was included in the fixed factor list. Thus, there were four fixed factors and two covariates for these feedback-related ERPs. Leveraging the MEM approach, we analysed multiple main effects and various interactions for each ERP component, as listed in Table 4.6.2.1 below. Additionally, we introduced a new nominal variable named ‘Congruency’, representing the interaction between Prediction and Feedback in analysing all FRPs. This new nominal variable enabled further pairwise comparisons among four congruency categories (e.g., YY, YN, NY, and NN). There was no requirement to apply these congruency categories when analysing SPN since this component occurred before feedback, leaving only two categories (i.e., 'Yes' Prediction vs. 'No' Prediction). The data for one participant was subsequently discarded due to insufficient trials for analysis. Consequently, the EEG data from 29 participants were analysed and reported below.

The Sidak method was used for adjusting confidence intervals when comparing main effects, as the commonly employed Bonferroni adjustment is overly conservative (Glickman et al., 2014), resulting in unnecessarily *small* adjusted p-values. For each mixed-effects model, we checked the multicollinearity of all predictors using Variance Inflation Factors (VIFs), and the low VIF values indicated that multicollinearity was not an issue for any of the mixed models. Therefore, the effects of the predictors on the ERP amplitude could be treated as independent of one another. We verified whether the dependent variables were normally distributed and found that all ERP components met this assumption. We performed diagnostics for outliers and influential points using distances (e.g., Cook's), residuals (e.g., studentised deleted residuals), and influence (e.g., DF beta and DF fit) statistics in SPSS. We concluded that there were no influential outliers. Finally, after constructing the models, we checked whether the model error was normal. All mixed-effects models reported here satisfied this assumption.

Table 4.6.2.1 Mixed model summary

Dependent Variables	**Random factor**	**Fixed factors/Covariate**
SPN (Fz, Cz, Pz)	Participant	**Main effect**: Gender, Prediction Valence, Electrode, SBS, NTS **Interaction effect**: Gender x Prediction Prediction x Electrode Prediction x SBS Prediction x NTS
FRN (Fz, Cz) P3a (Fz, Cz) P3b (Pz, P3, P4) LPP (Pz, P3, P4) LLPP (Pz, P3, P4)		**Main effect**: Gender, Prediction Valence, Feedback Valence, Electrode, SBS, NTS **Interaction effect**: Gender x Prediction Gender x Feedback Gender x Prediction x Feedback Prediction x Feedback Prediction x Electrode Feedback x Electrode Prediction x Feedback x Electrode Prediction x SBS Prediction x NTS Feedback x SBS Feedback x NTS Prediction x Feedback x SBS Prediction x Feedback x NTS

In addition, to gain a comprehensive view of the overall explanatory power of the mixed effect models, the Coefficient of Determination (R^2) was reported. The Coefficient of Determination, commonly known as R^2, measures the proportion of the variance in the dependent variable that is predictable from the independent variables. As Nakagawa and Schielzeth (2013) suggested, "R^2 has the extremely useful property of providing an absolute value for the goodness-of-fit of a model" (p.133), moreover, "as a summary statistic that describes the amount of variance explained, R^2 can also be a quantity of biological interest" (p.133). In mixed-effects models, R^2 can be decomposed into marginal R^2, concerned with variance explained by fixed effects only, and conditional R^2, concerned with variance explained by fixed and random effects (Nakagawa & Schielzeth, 2013). Both marginal R^2 and conditional R^2 convey unique and interesting information, and it is recommended to be presented in publication (Nakagawa & Schielzeth, 2013). Below is a summary of the Coefficient of Determination for each model. Marginal R^2 refers to the variance explained by fixed factors (Nakagawa & Schielzeth, 2013). For example, for the P3b, a Marginal R^2 of .188 for the model indicated that the fixed effects explained approximately 18.8% of the variance in P3b amplitude. Fixed effects are the predictors modelled as constants across all subjects, such as gender, Prediction Valence, Feedback Valence, electrode positions, SBS score, NTS score, and interaction terms. Conditional R^2 represents the variance explained by both fixed and random factors (Nakagawa & Schielzeth, 2013). A Conditional R^2 of .561 indicated that approximately 56.1% of the variance in P3b amplitude was explained when both fixed and random effects were considered. Random effects account for variability across subjects, reflecting individual differences not captured by the fixed effects alone.

Table 4.6.2.2 Explanatory power summary

Models	**Marginal R Square**	**Conditional R Square**
SPN	.115	.361
FRN	.194	.569
P3a	.091	.297
P3b	.188	.561
LPP	.186	.464
LLPP	.109	.441

As shown in the table above, the explanatory power of all models increased dramatically when both the fixed and random effects were considered. This indicates that a significant portion of the variability in the ERPs stemmed from individual differences or other random effects not captured by the fixed effects, implying that accounting for the random effect for a more accurate model was beneficial. Overall, given the high percentage of variance explained by the fixed and random effects, these mixed models fit the data well.

In the session below, findings on each ERP component will be reported separately. We primarily present the SPSS outputs of the Type III Tests of Fixed Effects and Estimated Marginal Means. Each table serves a different purpose in the context of mixed models. The Type III Tests of Fixed Effects concentrate on the overall significance of each predictor in the model and assess whether each fixed effect (independent variable/predictor) is significant while also considering other predictors in the model. Estimated Marginal Means provide the adjusted predicted means for each level of the fixed effect, aiding in the comparison of outcomes across different groups. They offer the predicted means for each level of the fixed effects, adjusted for other variables in the model. These means are valuable for understanding the effects of the predictors after accounting for the influence of other variables. By thoroughly interpreting the results of these outputs, we could have a comprehensive view of the significance and practical implications of the fixed effects in the models.

4.6.3 Stimulus Preceding Negativity (SPN)

The SPN has frequently been observed in anticipation of stimuli that carry emotional valence (for a comprehensive review, see Böcker et al., 2001). Furthermore, it is sensitive to the uncertainty of forthcoming stimuli (Catena et al., 2012; Tanovic & Joormann, 2019). It is measured while participants await the presentation of stimuli, specifically peer feedback, in this study. A total of 3500 ms segments were created to isolate the SPN, including a 200 ms post-feedback stimulus interval in the present study. These segments were deemed to capture the brain's predictive processes occurring from 3000 ms *prior to* the onset of the feedback stimulus. As in previous studies (Van der Molen et al., 2014), the 2400 – 2000 ms interval was employed for baseline correction, as this period likely marks the onset of the anticipation phase, and visual inspection confirmed the absence of any residual motor activity. In line with earlier research using the SJP, the SPN was calculated by extracting the mean amplitude within the

200 ms pre-feedback window (Kotani et al., 2001; Ohgami et al., 2004; Van der Molen et al., 2014).

The SPN is known to be pronounced at the medial frontal electrode (e.g., FCz) (Böcker et al., 2001), parietal and central sites (Kotani et al., 2003), parietal sites (Brunia & van Boxtel, 2004), and parietal-occipital electrode sites (Van der Molen et al., 2014) with adult samples. Additionally, in a sample of children aged between 6 and 10, Stavropoulos and Carver (2014a) discovered that the SPN amplitude in central and parietal electrodes was significantly larger than in temporal electrodes. Considering the adult and children's literature, the present study analysed the SPN amplitudes from frontal, central, and parietal electrodes, including Fz, Cz, and Pz.

A preliminary visual inspection revealed that the SPN amplitudes for No Prediction were more negative than those for Yes Prediction at the Fz, Cz, and Pz electrodes (see Figure 4.6.3.1). As shown in Figure 4.6.3.1 below, the SPN amplitudes for both Yes and No Prediction at Fz were the smallest among these three channels, followed by those at Cz. The SPN amplitudes for Yes and No Predictions were largest at Pz. The SPN amplitude difference between Cz and Pz for No Prediction was more pronounced than for Yes Prediction between these two channels. Additionally, the amplitude difference between Yes and No Predictions was greatest at Fz, followed by Cz, while this difference was less apparent at Cz and Pz. Statistical analysis confirmed these observations, as detailed below.

As discussed earlier, a mixed-effects model was built to investigate the relationships between SPN and various predictors (e.g., gender, Prediction Valence, electrode, SBS, and NTS) and multiple interaction effects. The detailed results are given below.

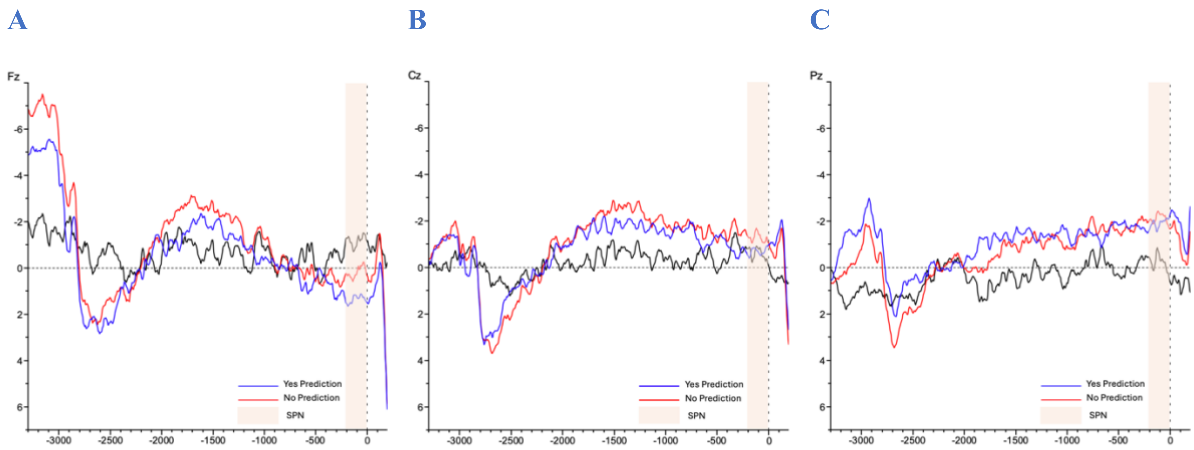


Figure 4.6.3.1 SPN grand averaged waveforms by Prediction Valence

Note. The figures show grand averaged waveforms from two conditions, Yes Prediction (in blue) and No Prediction (in red), extracted from Fz (A), Cz (B), and Pz (C) channels. They show the SPN between -200 ms and 0 ms, as highlighted, before the onset of feedback stimuli, indicated as

Prediction Valence and the SPN amplitude

Prediction Valence Prediction Valence was a significant predictor of SPN amplitude in the mixed-effects model, F (1, 300) = 5.976, p = .015, indicating that this factor significantly influenced the SPN amplitude while taking into account all other predictors and interaction effects in the model. According to the model prediction, the marginal means of the SPN amplitude for No Prediction (M = -3.917, SE = .729) was larger than that for Yes Prediction (M = -3.585, SE = .729). However, when the main effect from the channels was not considered, this difference did not reach significance, $|M_{diff}|$ = .332, SE = .567, df = 300, p = .559, 95% CI [-.783, 1.447]. In the visual inspection of the grand averaged waves across different channels, the SPN amplitude differences between Yes and No Prediction varied, with Fz displaying the most substantial SPN difference for different Prediction Valences, while the differences at Cz and Pz were less pronounced. Therefore, when averaged across the three channels, there was no significant SPN amplitude difference between Yes and No Prediction (see Figure 4.6.3.2).

Figure 4.6.3.3 presents grand average topographical maps of the SPN for Yes Prediction (A) and No Prediction (B).

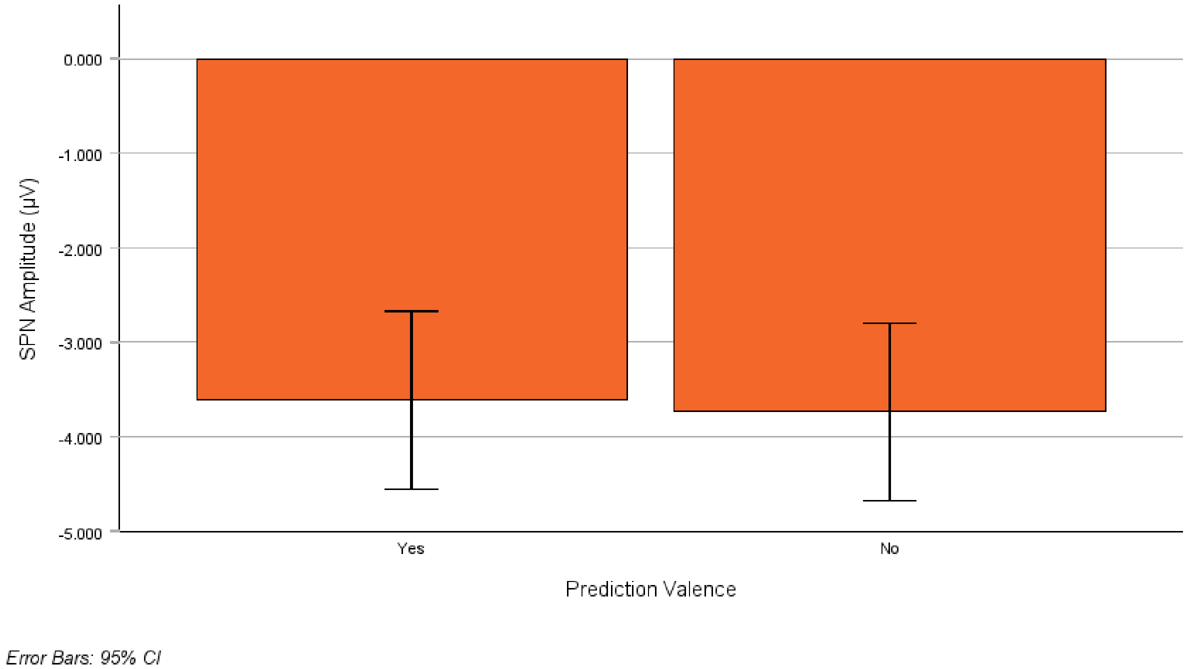


Figure 4.6.3.2 Averaged SPN amplitudes by Prediction Valence

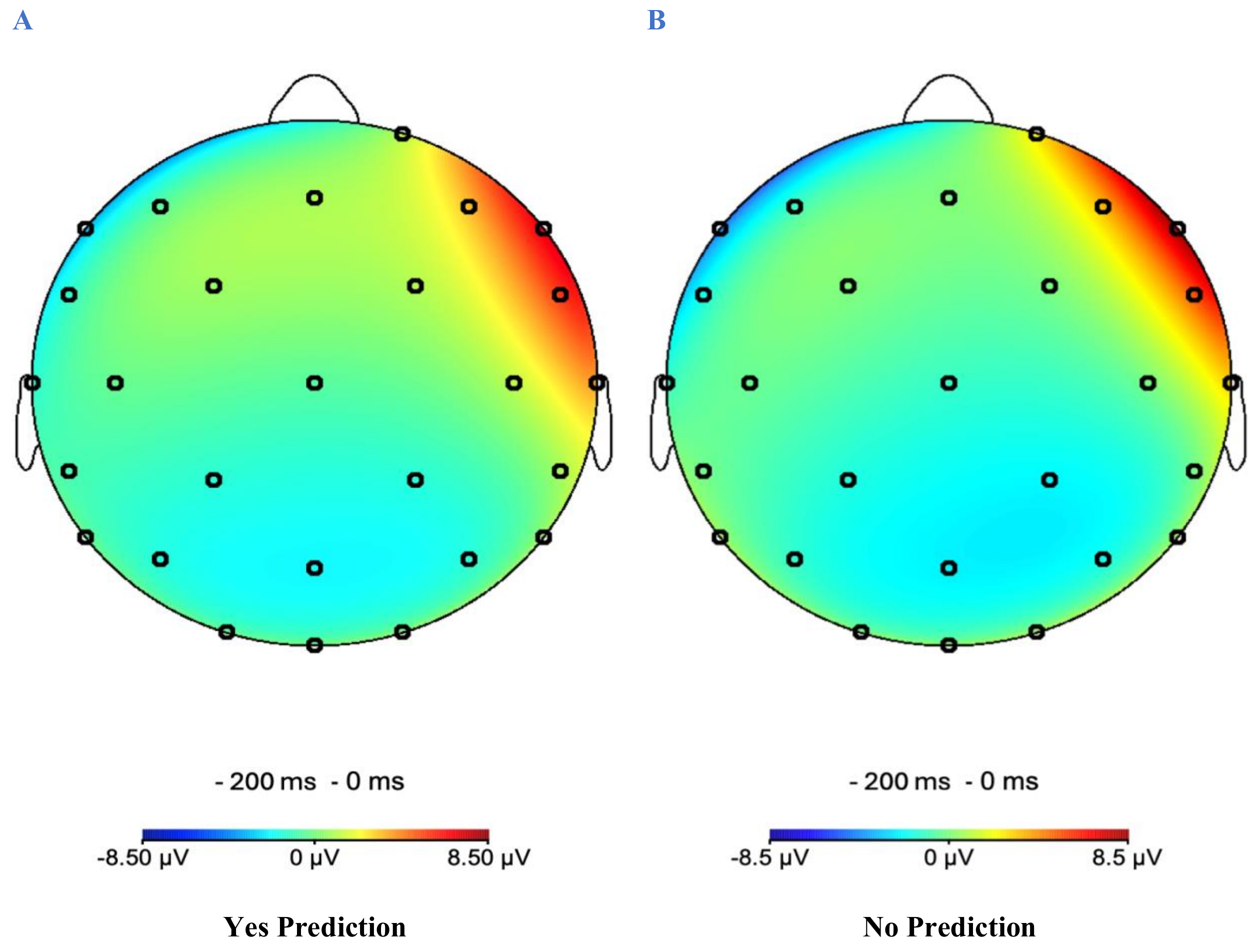


Figure 4.6.3.3 Grand average topographical maps of the SPN

Prediction Valence x *the SPN electrodes* Overall interaction effect of Prediction Valance x the SPN Electrodes was not found; *F* (2,300) = 1.709, *p* = .183. However, controlling for the electrodes, the pairwise comparison showed that the main difference in SPN amplitude arose solely from the variation between Fz (*M* = -1.759, *SE* = .922) and Pz (*M* = -5.115, *SE* = .922) when Prediction Valence was positive, $|M_{diff}|$ = 3.355, *SE* = .979, *df* = 300, *p* = .002, 95% *CI* [1.005, 5.706] (see Figure 4.6.3.4A). In other words, the SPN at Fz was statistically different from the SPN at Pz only when the prediction was positive. None of the differences in Figure 4.6.3.4B were statistically significant.

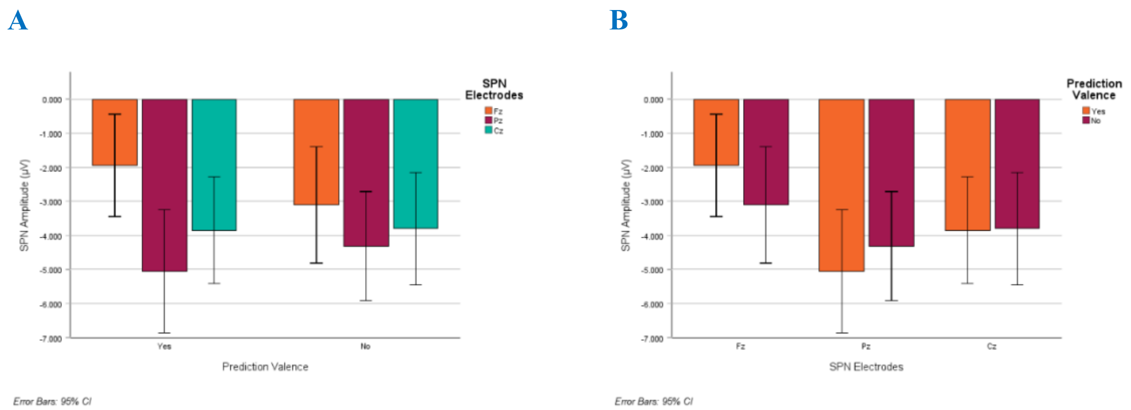


Figure 4.6.3.4 Averaged SPN amplitudes by Prediction Valence and the electrodes

Gender and the SPN amplitude

Gender No significant main effect of gender was found, F (1, 24.001) = .072, p = .791. As illustrated in Figure 4.6.3.5, the SPN amplitude difference between genders was not significant.

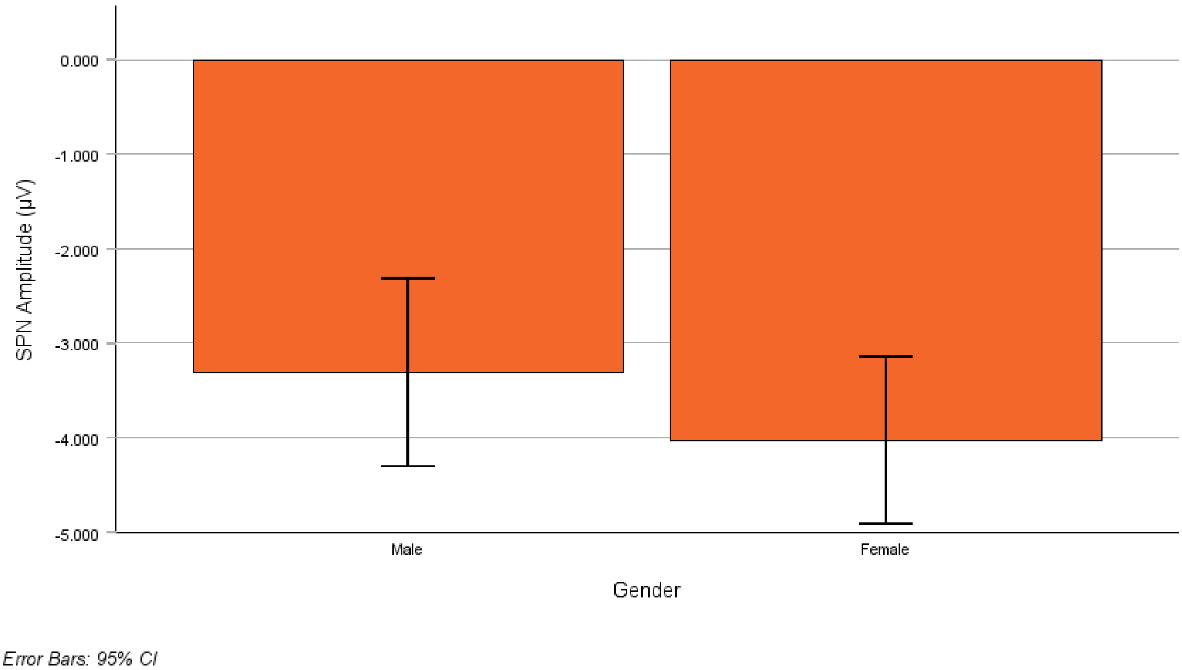


Figure 4.6.3.5 Averaged SPN amplitudes by gender

Prediction Valence x Gender There was no interaction effect of Prediction Valence x Gender, F (1, 300) = .690, p = .407. Figure 4.6.3.6 illustrates amplitudes from each gender group at two different prediction valences.

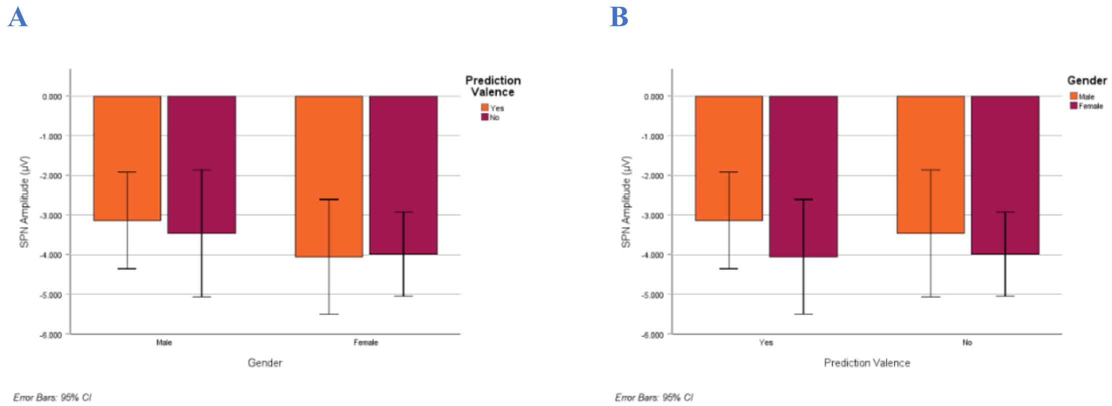


Figure 4.6.3.6 Averaged SPN amplitudes by gender and Prediction Valence

Electrodes and the SPN amplitude

Electrodes The electrodes significantly predicted the SPN amplitude, F (2,300) = 4.672, p = .010. A pairwise comparison showed none of the differences between the three channels were significant (see Figure 4.6.3.7). These means were calculated across Prediction Valences.

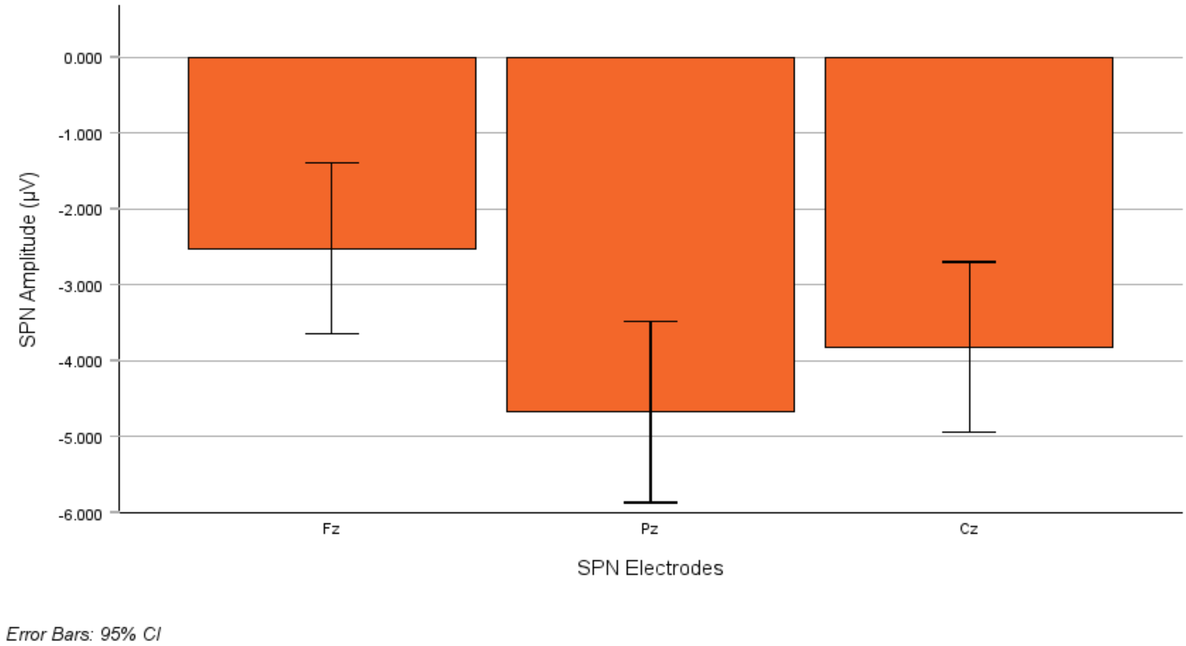


Figure 4.6.3.7 Averaged SPN amplitudes by the electrodes

NTS and the SPN amplitude

NTS No significant main effect of the NTS scores on the SPN amplitude was revealed, F (1, 24.001) = .593, p = .449. However, the interaction effect of Prediction Valence x NTS Scores was statistically significant, F (1, 300) = 4.710, p = .031. To illustrate the correlation between NTS and SPN amplitude, we first calculated the SPN prediction difference wave amplitude for each participant by subtracting their SPN amplitude for Yes Prediction from their SPN amplitude for No Prediction (i.e. $SPN_{No} - SPN_{Yes}$). Then we drew a scatterplot showing NTS against the SPN prediction difference wave. Each dot on the scatterplot represented a participant along with their NTS score and SPN difference wave amplitude. The slope illustrated the relationship between NTS and SPN.

Given that the SPN amplitude is negative, a greater negativity of the SPN prediction difference wave reflects a larger SPN amplitude for No Prediction than for Yes Prediction. In other words, a larger SPN prediction difference wave signifies a greater SPN amplitude following a No Prediction than a Yes Prediction. As shown in Figure 4.6.3.8 below, it is evident that a higher amplitude of the SPN observed after predictions of rejection, as opposed to acceptance, correlates with a reduced level of exclusion distress experienced by participants during the social exclusion experiment. This correlation yields a difference amplitude below zero and becomes more negative.

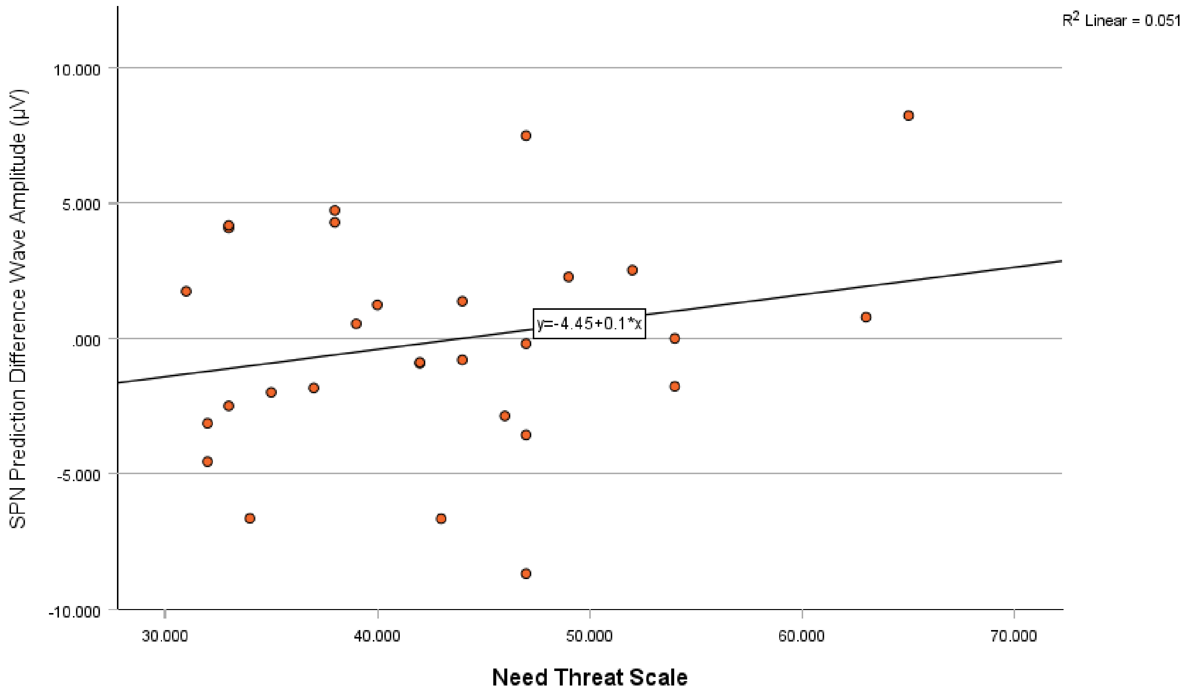


Figure 4.6.3.8 Correlation between NTS and the SPN prediction difference amplitude

SBS and the SPN amplitude

SBS The SBS scores had a significant main effect on the SPN amplitude: F (1, 24.001) = 4.773, p = .039. As discussed above, we also constructed a scatter plot showing the relationship between the SBS and the SPN prediction difference wave (See Figure 4.6.3.9). Additionally, the interaction effect of Prediction Valuation x SBS Scores was marginally significant: F (1, 300) = 3.366, p = .068. Figure 4.6.3.9 indicates that the less one felt a sense of belonging to the school, the greater the SPN amplitude after predicting rejection compared to acceptance, resulting in a difference amplitude below zero and more negative. In other words, a child's sense of belonging at school might influence their anticipation of social feedback, as indicated by the SPN.

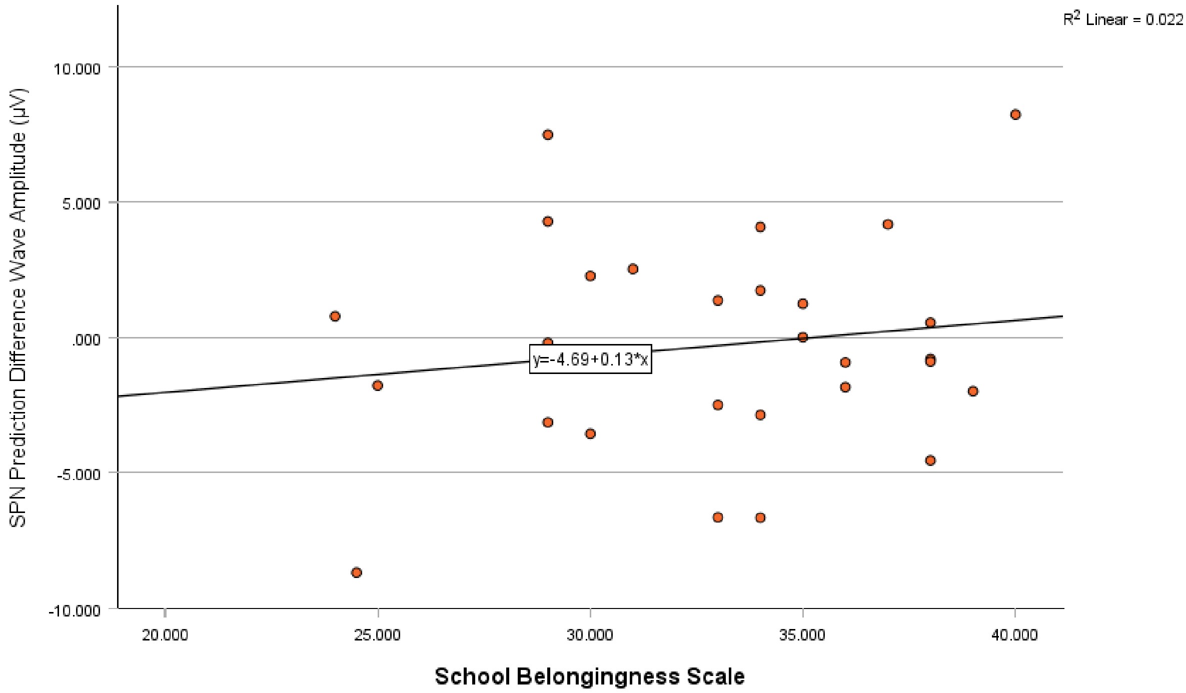


Figure 4.6.3.9 Correlation between SBS and the SPN prediction difference amplitude

In summary, the model revealed three significant main effects on SPN amplitude: Prediction Valence, SPN electrodes, and SBS scores. The Prediction Valence x NTS scores exhibited a significant interaction effect, while the Prediction Valence x SBS scores showed a marginally significant impact.

The SPN discussed above was the only ERP component examined before the feedback onset in the current study. Subsequent sections will elaborate on the FRPs, including the FRN, P3a, P3b, LPP, and LLPP.

4.6.4 Feedback Related Negativity (FRN)

The FRN encodes feedback in a binary manner (e.g., positive vs. negative) (see Ullsperger et al., 2014, for a review) and is sensitive to expectation violations (see Gu et al., 2020, for a review). It is a stimulus-locked component characterised by negative polarity. In previous SJP studies, the FRN was prominent at FCz (van der Veen et al., 2016) and Fz (Dekkers et al., 2015). Consistent with earlier ERP studies employing the same experimental task (Dekkers et al., 2015; van der Veen et al., 2016), the FRN was extracted from Fz and Cz and calculated using a peak-to-peak detection method: first, identifying the P2 component (i.e., the most positive value in the 150–250 ms post-feedback window) as the onset of negativity; second, determining the most negative peak within a window from 200 to 350 ms post-feedback (i.e., FRN time-window); finally, the P2 component was subtracted from the most negative peak that followed it, and the difference between these two values was defined as the FRN amplitude.

Prediction Valence and the FRN

The preliminary visual inspection of the grand averaged waveforms of the FRN for Yes Prediction and No Prediction, extracted from the Fz and Cz channels within the FRN time window of 250 to 350 milliseconds, indicated that the FRN amplitude for No Prediction, after being subtracted from the P2 amplitude, was greater than the FRN for Yes Prediction at both Fz and Cz (see Figure 4.6.4.1). Statistical analysis supported these observations.

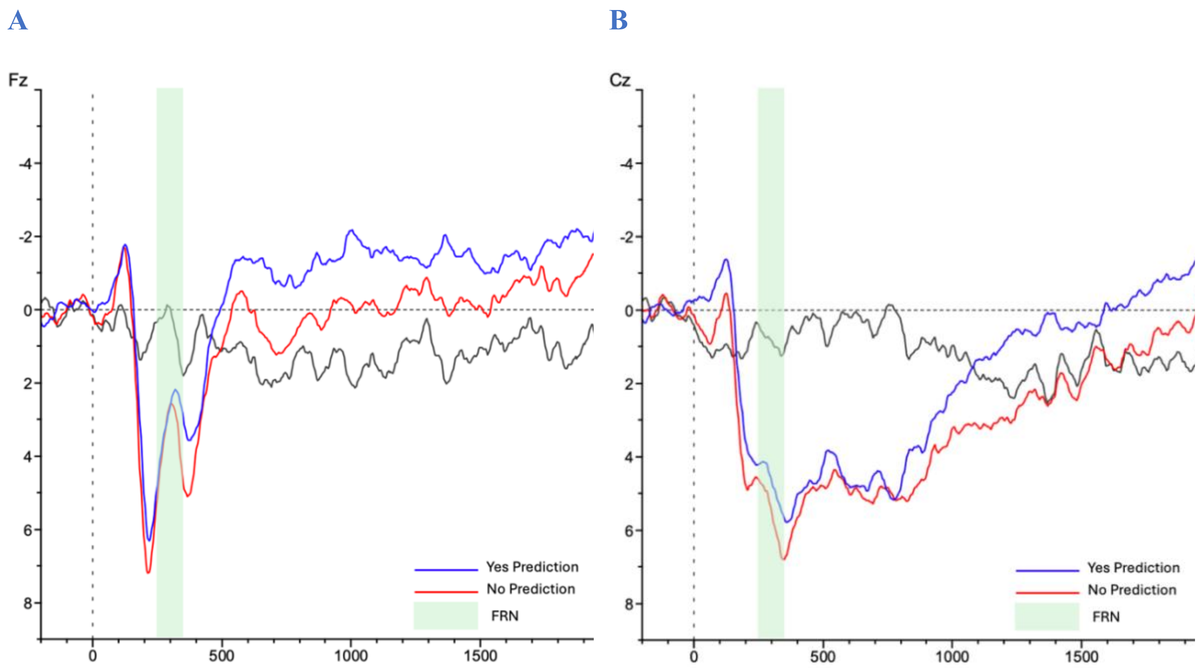


Figure 4.6.4.1 FRN grand averaged waveforms by Prediction Valence

Note: The figures depict grand averaged waveforms from two conditions: Yes Prediction (shown in blue) and No Prediction (shown in red), extracted from the Fz (A) and Cz (B) channels. These waveforms represent the FRN occurring between 250 ms and 350 ms, as highlighted, after the onset of feedback stimuli, indicated as 0.

Prediction Valence The model indicated a significant effect of Prediction Valence on the FRN amplitude, F (1,180) = 7.195, p = .008. According to the model's predictions, the estimated marginal means of the FRN amplitude for No Prediction (M = - 6.027, SE = .675) was greater than that for Yes Prediction (M = - 5.109, SE = .675). These means were averaged across two channels: Fz and Cz. A pairwise comparison revealed that the mean difference between Yes and No Prediction was statistically significant, $|M_{diff}|$ = .918, SE = .451, df = 180, p = .043, 95% CI [.028, 1.808] (see Figure 4.6.4.2).

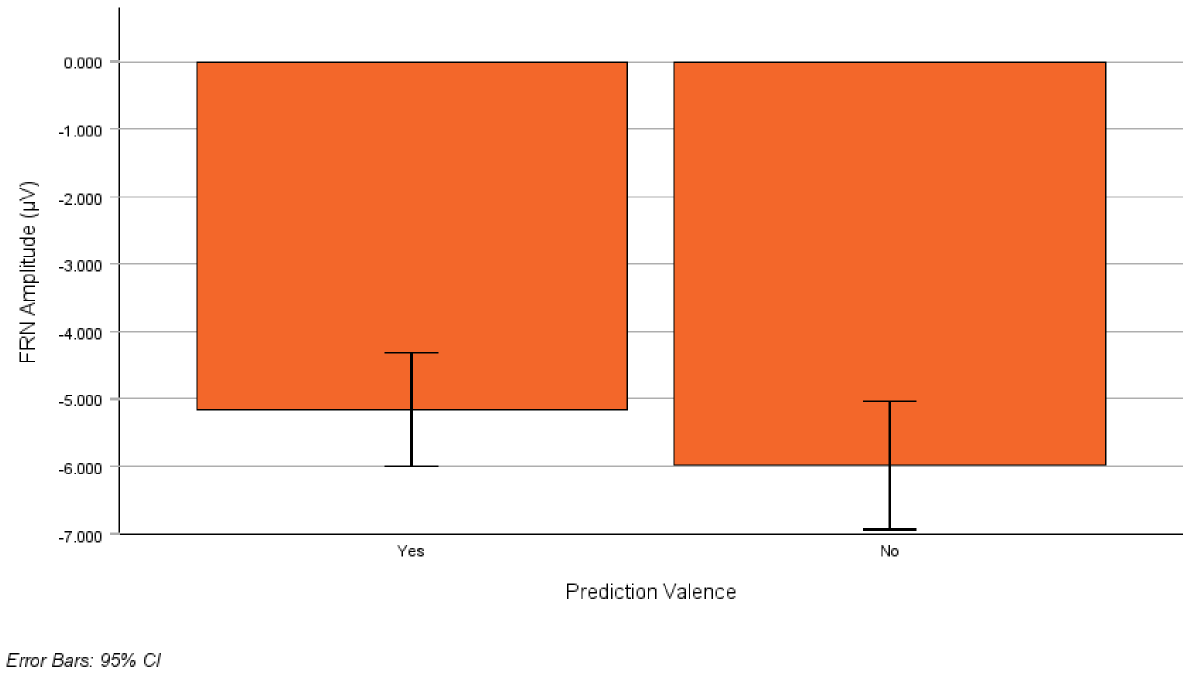


Figure 4.6.4.2 Averaged FRN amplitudes by Prediction Valence

Prediction Valence x the FRN Electrodes The model showed no significant interaction effect between the Prediction Valence and the FRN electrodes: F (1, 180) = .114, p = .736. However, the model's estimated marginal means revealed significant differences in FRN amplitude between Fz and Cz for both Yes and No Predictions (see Figure 4.6.4.3A). None of the differences in 4.6.4.3B were statistically significant.

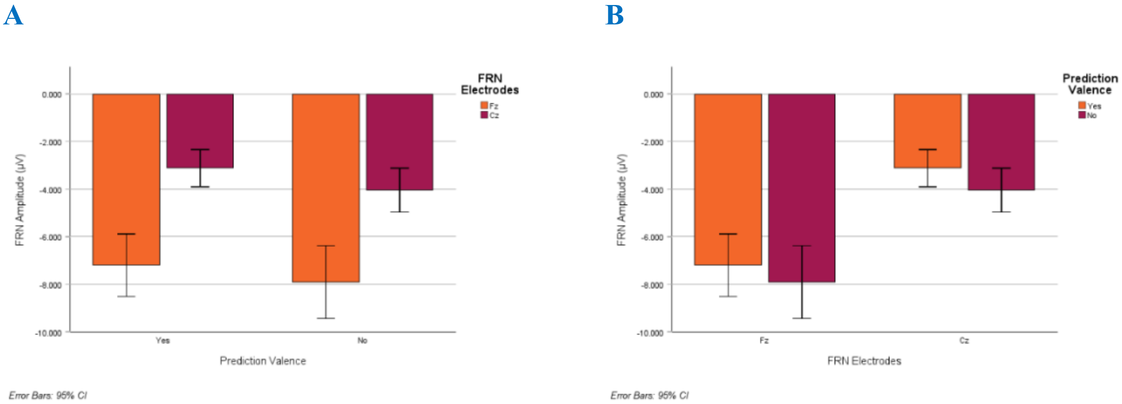


Figure 4.6.4.3 Averaged FRN amplitudes by Prediction Valence and the electrodes

Feedback Valence and the FRN

The preliminary visual inspection of the grand averaged waveforms of FRN for Yes Feedback and No Feedback, extracted from the Fz and Cz channels in the FRN time window between 250 to 350 milliseconds, indicated that the FRN amplitude for No Feedback, once subtracted from the P2 amplitude, was greater than the FRN for Yes Feedback at both Fz and Cz (refer to Figure 4.6.4.4). The subsequent statistical analysis corroborated these observations.

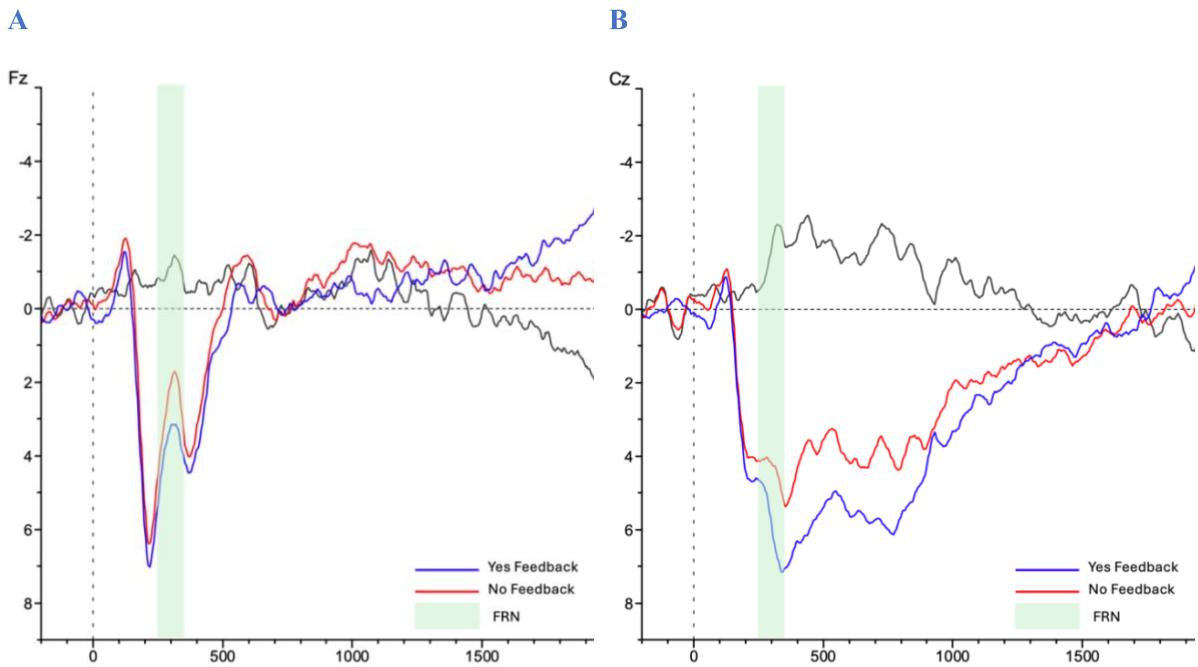


Figure 4.6.4.4 FRN grand averaged waveforms by Feedback Valence

Note: The figures show grand averaged waveforms from two conditions: Yes Feedback (in blue) and No Feedback (in red), extracted from the Fz (A) and Cz (B) channels. They illustrate the FRN occurring between 250 ms and 350 ms, as highlighted, following the onset of feedback stimuli, indicated as 0.

Feedback Valence The results of average FRN amplitudes per Feedback Valence across two channels are shown in Figure 4.6.4.5. The model revealed no main effect of Feedback Valence, F (1, 180) = .062, p = .804. However, the model's estimated marginal mean suggested a significant difference in FRN amplitude between Yes (M = -5.063, SE = .675) and No Feedback (M = -6.074, SE = .675) at Fz and Cz, with No Feedback displaying a significantly higher FRN amplitude than Yes Feedback, $|M_{diff}|$ = 1.011, SE = .451, df = 180, p = .026, 95% CI [.121, 1.901]. Furthermore, Feedback Valence did not interact with any other predictors in the model.

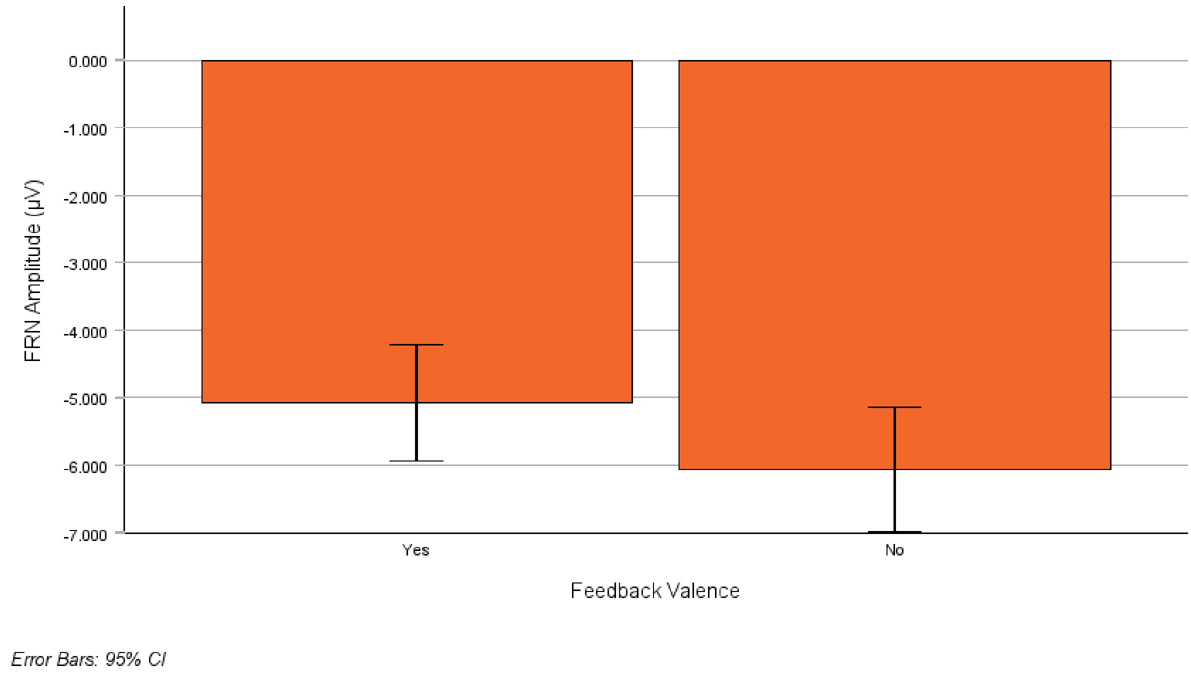


Figure 4.6.4.5 Averaged FRN amplitudes by Feedback Valence

Feedback Valence x the FRN Electrodes There was no significant interaction effect between Feedback Valence and the FRN electrodes, F (1,180) = .373, p = .542. However, as illustrated in Figure 4.6.4.6A, further pairwise comparisons separating the FRN at Fz and Cz indicated that the difference between Yes and No Feedback primarily stemmed from Cz. When comparing Feedback Valence for 'Yes' and 'No', a significant difference in FRN amplitude was observed at Cz, while this difference at Fz was not significant. Additionally, as shown in

Figure 4.6.4.6B, there were significant FRN amplitude differences between Yes and No Feedback at Fz and Cz. Figure 4.6.4.7 presents the grand average topographical maps of the FRN for Yes Feedback (A) and No Feedback (B).

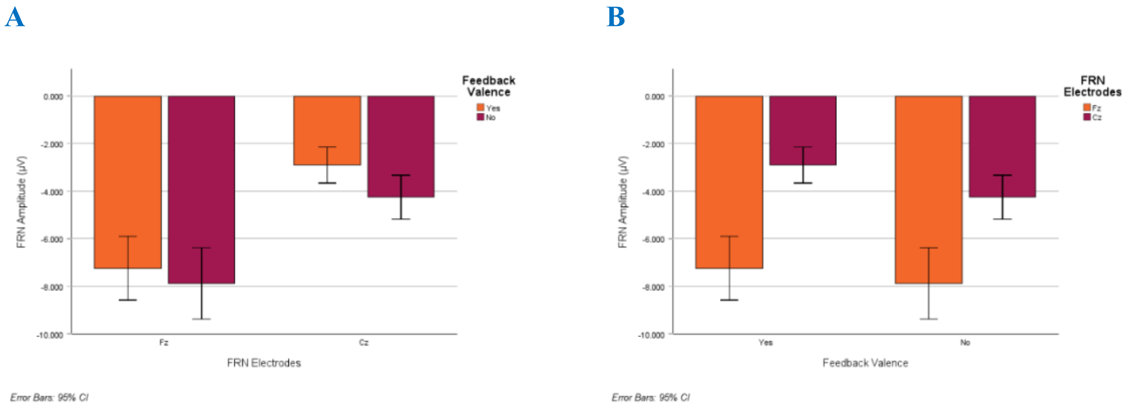


Figure 4.6.4.6 Averaged FRN amplitudes by Feedback Valence and the electrodes

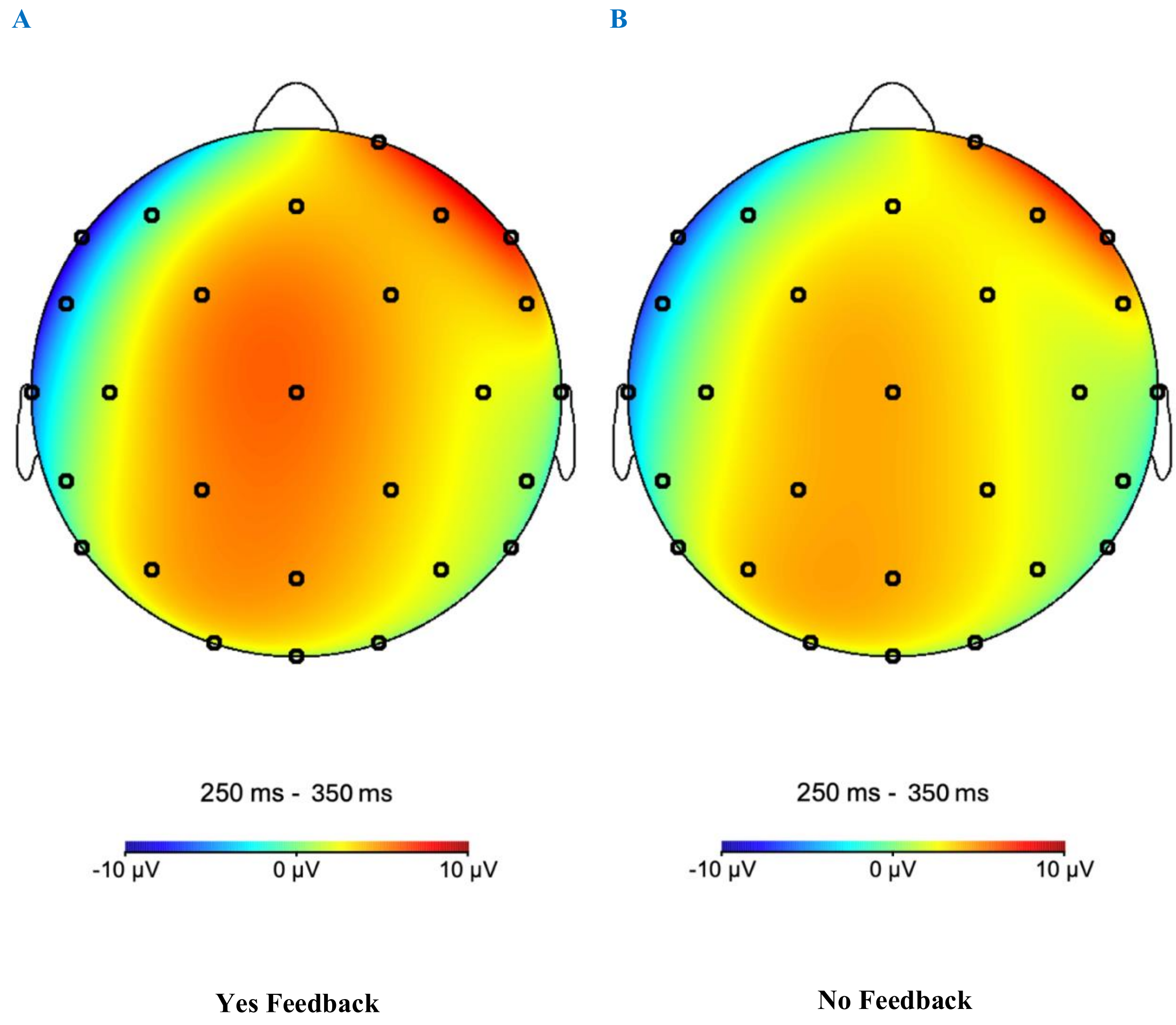


Figure 4.6.4.7 Grand average topographical maps of the FRN

Congruency and the FRN

The preliminary visual inspection of the grand averaged waveforms of the FRN for four contingency types (YY, YN, NY, and NN), extracted from the Fz and Cz channels within the FRN time window of 250 to 350 milliseconds, indicated that the FRN amplitude for expected rejection (NN), after being subtracted from the P2 amplitude, was the largest among the four contingency categories at Fz and Cz (see Figure 4.6.4.8). In addition, the FRN for expected acceptance (YY), after being subtracted from the P2 amplitude, was the smallest among the four contingency categories at Fz and Cz (see Figure 4.6.4.8). The statistical analysis reported below confirmed these observations.

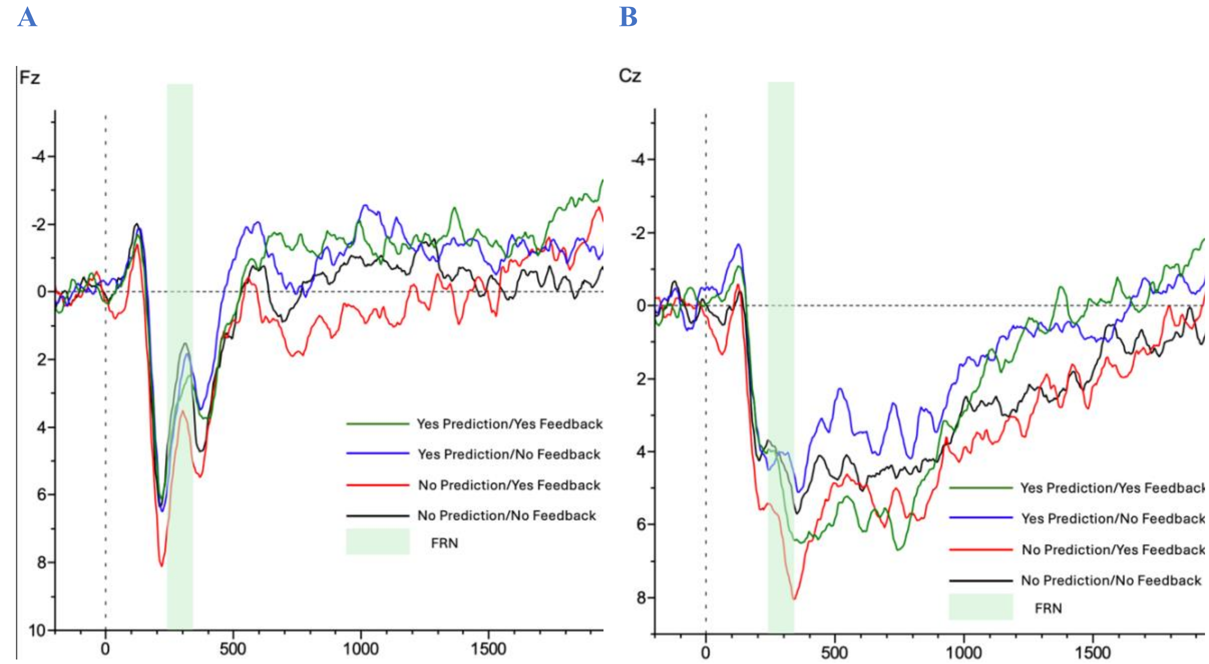


Figure 4.6.4.8 FRN grand averaged waveforms by congruency type

Note: The figures illustrate the grand averaged waveforms from four contingency conditions: YY (in green), YN (in blue), NY (in red), and NN (in black). These waveforms are derived from the Fz (A) and Cz (B) channels. They depict the FRN occurring between 250 ms and 350 ms, as highlighted, after the onset of feedback stimuli, indicated as 0.

Congruency There was no interaction effect between Prediction Valence and Feedback Valence, F (1,180) = .584, p = .446. As illustrated in Figure 4.6.4.9, the FRN for expected rejection (NN) (M = -6.408, SE = .746) was the largest, followed by the FRN for unexpected rejection (YN) (M = -5.740, SE = .746). The FRN for unexpected acceptance (NY) (M = -5.647, SE = .746) was the second smallest, while the FRN for expected acceptance (YY) (M = -4.479, SE = .746) was the smallest. The model estimated marginal means indicated a significant difference in FRN amplitude between expected acceptance (YY) and expected rejection (NN) when averaged across Fz and Cz. Specifically, expected rejection (NN) displayed a higher FRN amplitude than expected acceptance (YY), $|M_{diff}|$ = 1.929, SE = .638, df = 180, p = .017, 95%

CI [.232, 3.625] (refer to Figure 4.6.4.9). No other significant differences were found among the four congruency groups when averaged across Fz and Cz (see Figure 4.6.4.9). Figure 4.6.4.9 presents the averaged FRN amplitude means across Fz and Cz for the four congruency types.

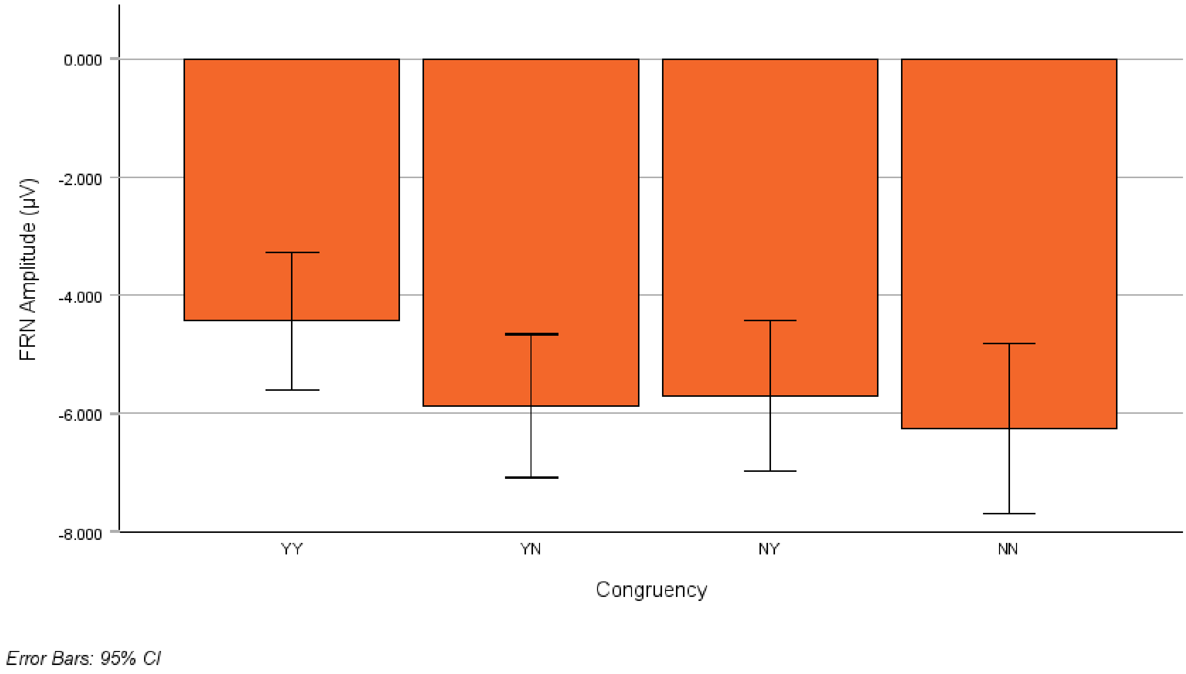


Figure 4.6.4.9 Averaged FRN amplitudes by congruency type

Congruency x *the FRN electrodes* There was no significant interaction effect of Prediction Valence, Feedback Valence, and the FRN electrodes, F (1,180) = .003, p = .954. Figure 4.6.4.10A displays the averaged means of the FRN amplitude at Fz and Cz for four distinct congruency types. As mentioned earlier, when averaged across both channels, a significant difference in FRN amplitude was observed between expected rejection (NN) and acceptance (YY). As illustrated in Figure 4.6.4.10A, this difference primarily originated from Cz rather than Fz.

Figure 4.6.4.10B displays the FRN amplitudes at Fz and Cz for each congruency type separately. As indicated in Table 4.6.4.1, significant differences in FRN amplitude were observed between Fz and Cz across all four congruency types.

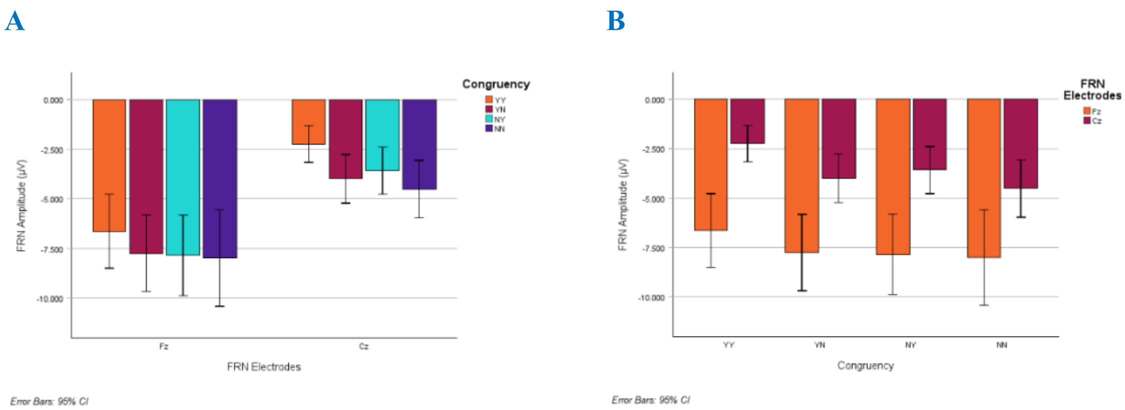


Figure 4.6.4.10 Averaged FRN amplitudes by congruency type and electrode

Table 4.6.4.1 Pairwise comparisons for the FRN congruency types

Congruency	(I) FRN Electrodes	(J) FRN Electrodes	Mean Difference (I-J)	Std. Error	*df*	*Sig.*[c]	95% Confidence Interval for Difference[c]	
							Lower Bound	Upper Bound
YY	Fz	Cz	-4.280*	.900	180.000	<.001	-6.055	-2.505
YN	Fz	Cz	-3.782*	.900	180.000	<.001	-5.557	-2.007
NY	Fz	Cz	-4.028*	.900	180.000	<.001	-5.803	-2.253
NN	Fz	Cz	-3.426*	.900	180.000	<.001	-6.055	-2.505

Gender and the FRN

Gender No significant main effect of gender was observed; F (1, 24) = .047, p = .830. Figure 4.6.4.11 displayed no significant difference in FRN between genders.

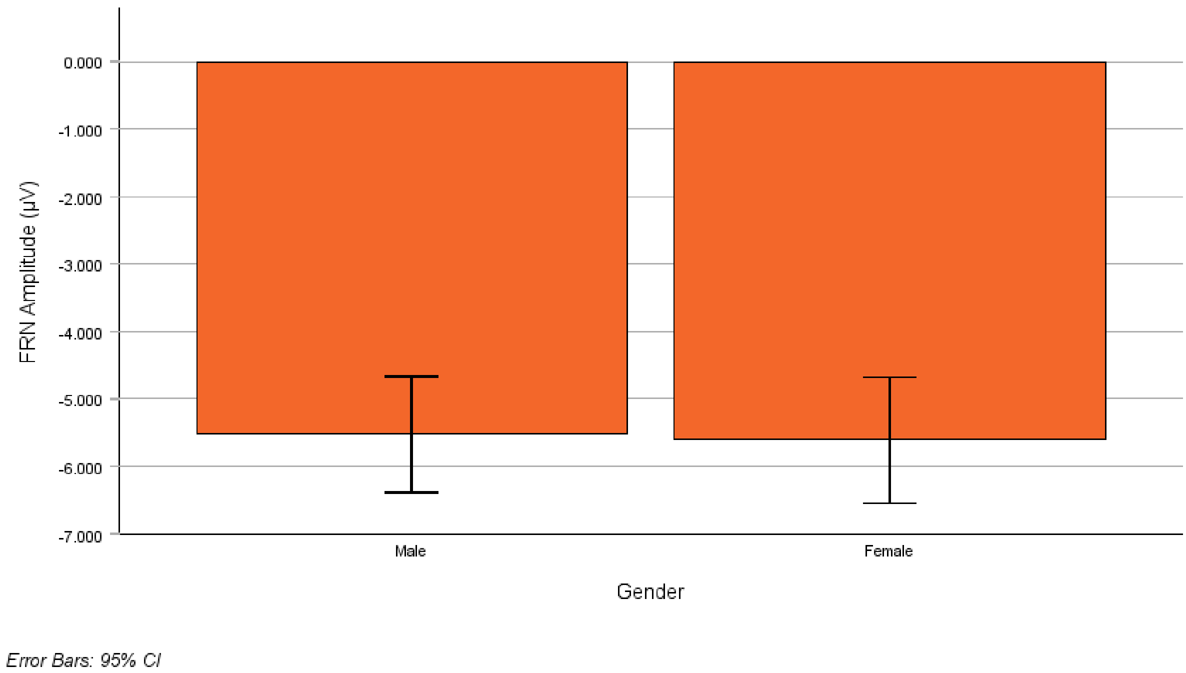


Figure 4.6.4.11 Averaged FRN amplitudes by gender

Gender x *Prediction Valence* There was no significant interaction effect between gender and Prediction Valence, F (1, 180) = .261, p = .610. None of the differences displayed in Figure 4.6.4.12 were statistically significant.

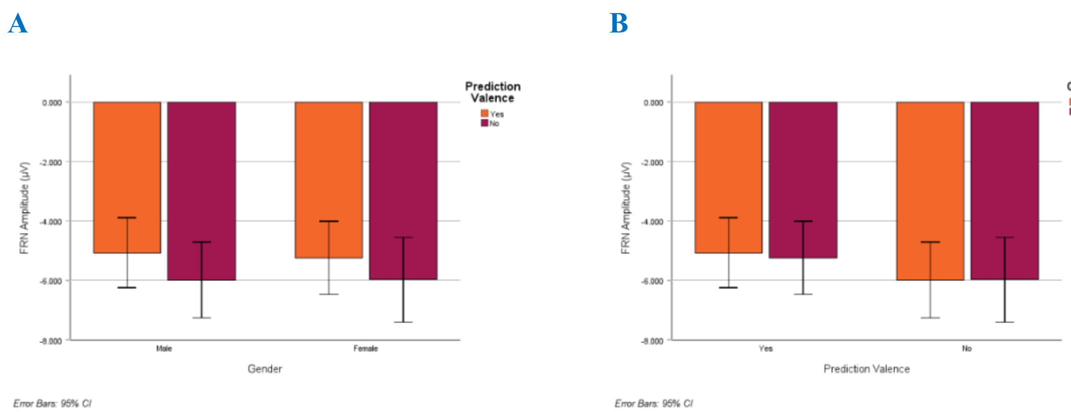


Figure 4.6.4.12 Averaged FRN amplitudes by gender and Prediction Valence

Gender x *Feedback Valence* There was no significant interaction effect between gender and Feedback Valence, F (1, 180) = 1.396, p = .239. Figure 4.6.4.13A illustrates that the FRN for

No Feedback was greater than for Yes Feedback across both genders. However, the difference between Yes Feedback (*M* = -4.643, *SE* = 1.008) and No Feedback (*M* = -6.207, *SE* = 1.008) was statistically significant only for the boys: $|M_{diff}|$ = 1.564, *SE* = .674, *df* = 180, *p* = .021, 95% *CI* [.234, 2.893]. Additionally, none of the differences shown in Figure 4.6.4.13B were statistically significant.

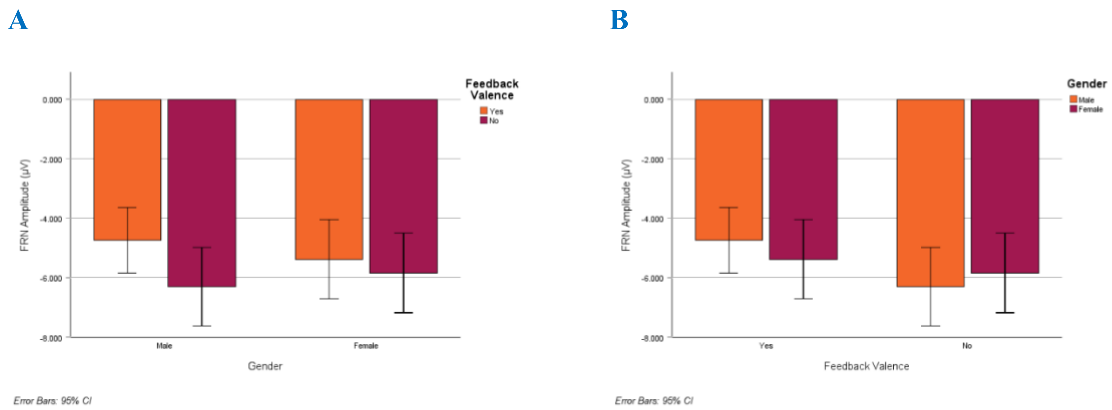


Figure 4.6.4.13 Averaged FRN amplitudes by gender and Feedback Valence

Gender x *Congruency* There was no significant interaction effect between gender and congruency, *F* (1, 180) = 1.782, *p* = .184. Figure 4.6.4.14A compares the FRN amplitudes for four congruency types within each gender, while Figure 4.6.4.14B compares the gender differences within each congruency type. Among all these comparisons, only the FRN difference between expected acceptance (YY) (*M* = -4.252, *SE* = 1.115) and expected rejection (NN) (*M* = -6.973, *SE* = 1.115) for the boys was statistically significant, $|M_{diff}|$ = 2.721, *SE* = .953, *df* = 180, *p* = .028, 95% *CI* [.186, 5.255]. For the girls, none of the differences displayed in Figure 4.6.4.14 were significant.

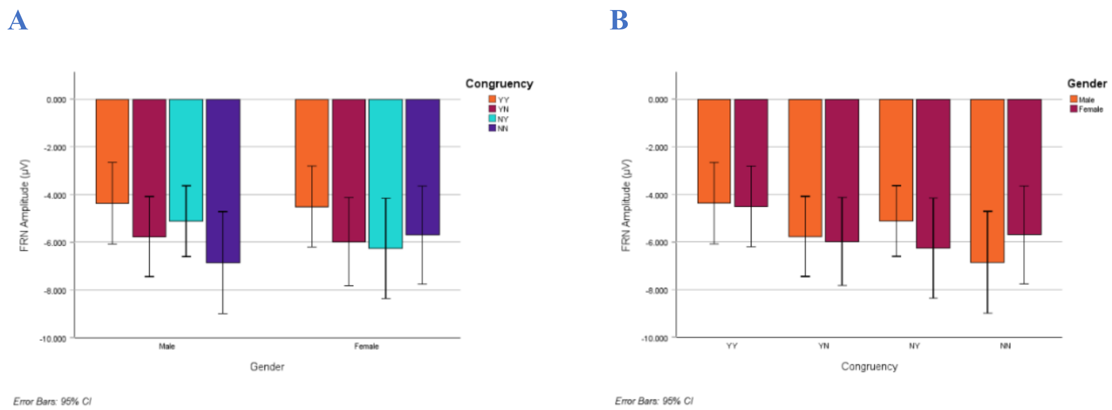


Figure 4.6.4.14 Averaged FRN amplitudes by gender and congruency

Electrode and the FRN

Electrode Electrode had a statistically significant main effect on the FRN, F (1, 180) = 74.384, p < .001. According to the model prediction, the estimated marginal means of the FRN amplitude at Fz (M = -7.508, SE = .675) were larger than the FRN at Cz (M = -3.629, SE = .675) (see Figure 4.6.4.12). A pairwise comparison showed that the mean difference between Fz and Cz was statistically significant, $|M_{diff}|$ = 3.879, SE = .450, df = 180, p < .001, 95% CI [-4.767, -2.992]. The electrode did not demonstrate any interaction effect with other predictors in the model.

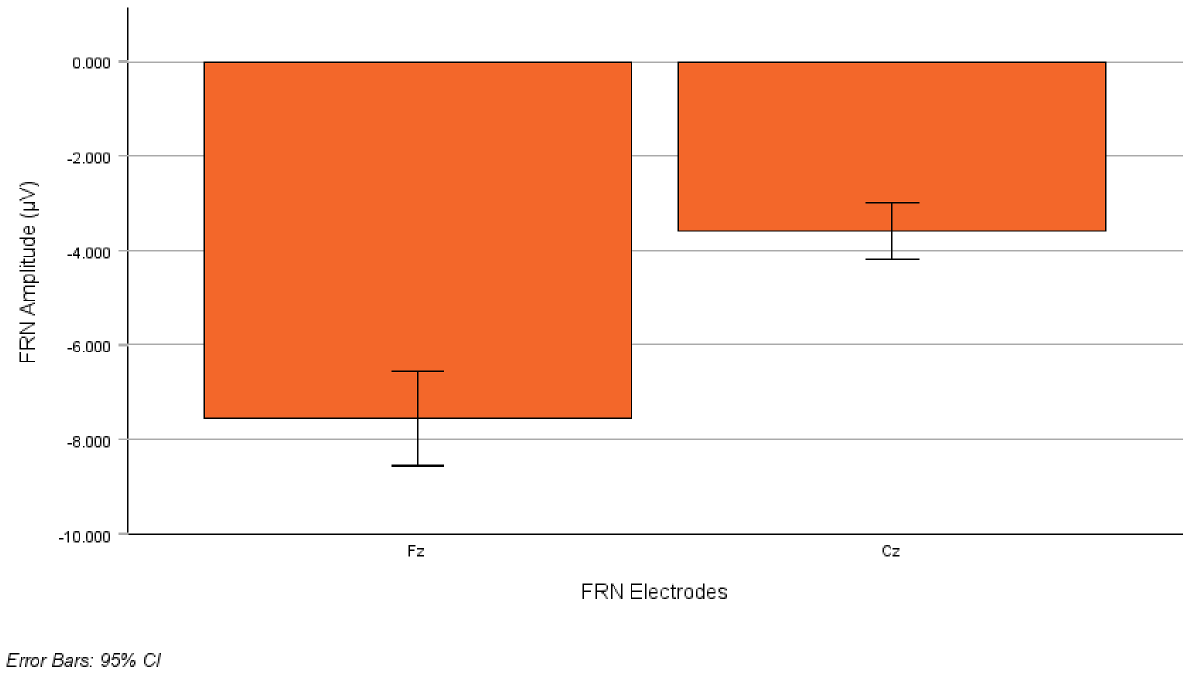


Figure 4.6.4.15 Averaged FRN amplitudes by electrodes

NTS and the FRN

NTS No main effect of the NTS scores on the FRN was found, F (1, 24) = .090, p = .767. However, a significant interaction effect was observed between Prediction Valence and NTS, F (1, 180) = 5.616, p = .019. To illustrate the correlation between NTS and FRN amplitude, we first calculated the FRN difference amplitude for each participant by subtracting their FRN amplitude for Yes Prediction from their FRN amplitude for No Prediction (i.e. FRN_{NO}-FRN_{YES}). We then created a scatterplot to show the relationship between NTS and the FRN prediction difference wave. Each dot on the scatterplot represented an individual participant, along with their corresponding NTS score and FRN difference amplitude value. The slope depicted the relationship between NTS and FRN difference amplitude. Given that the FRN amplitude is negative, a more negative FRN prediction difference wave indicated a larger FRN amplitude for No Prediction than for Yes Prediction. In other words, a greater FRN prediction difference wave signified a larger FRN amplitude following a No Prediction than following a

Yes Prediction. As shown in Figure 4.6.4.16 below, an increased FRN amplitude following the anticipation of rejection was associated with reduced exclusion distress among participants during the social exclusion experiment, resulting in an amplitude difference below zero and more negative. In other words, a child's conscious social prediction of peer social feedback (namely, being accepted versus being rejected) could play a crucial role in moderating the relationship between young children's immediate post-hoc feedback appraisal, as indexed by the FRN, and their perceived distress from exclusion.

Additionally, no significant interaction effect was found for Feedback Valence x NTS, F (1, 180) = .256, p = .614 (see Figure 4.6.4.17). Furthermore, there was no interaction effect between congruency and NTS, F (1, 180) = .040, p = .841.

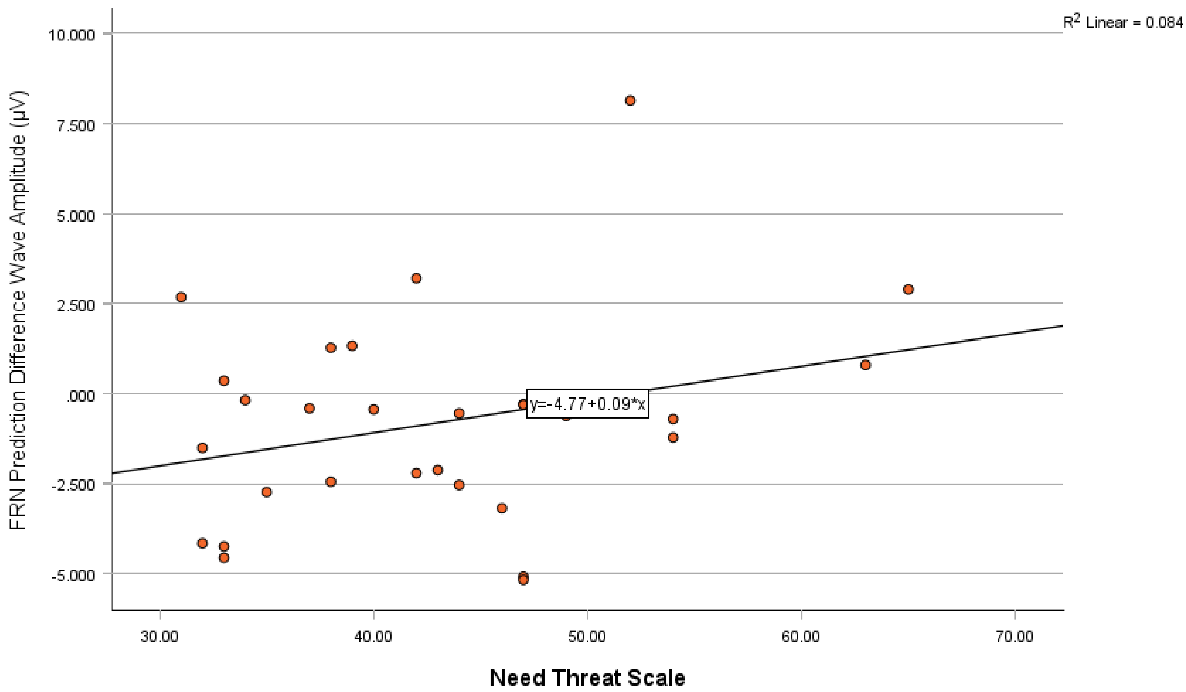


Figure 4.6.4.16 Correlation between NTS and the FRN prediction difference amplitude

SBS and the FRN

No significant main effect of the SBS scores on the FRN was observed, F (1, 24) = .200, p = .658. Nevertheless, there was a marginally significant interaction effect of Prediction Valence x SBS, F (1, 180) = 3.422, p = .066. As discussed earlier, we also created a scatter plot illustrating the relationship between the SBS and the FRN prediction difference wave. Figure 4.6.4.17 indicates that individuals who felt less belonging to the school exhibited a larger FRN amplitude after predicting rejection, in comparison to acceptance, resulting in a difference amplitude below zero and more negative.

Additionally, there was no significant interaction effect between Feedback Valence and SBS, F (1, 180) = .085, p = .771. Moreover, there was no interaction effect between congruency and SBS, F (1, 180) = 1.152, p = .284.

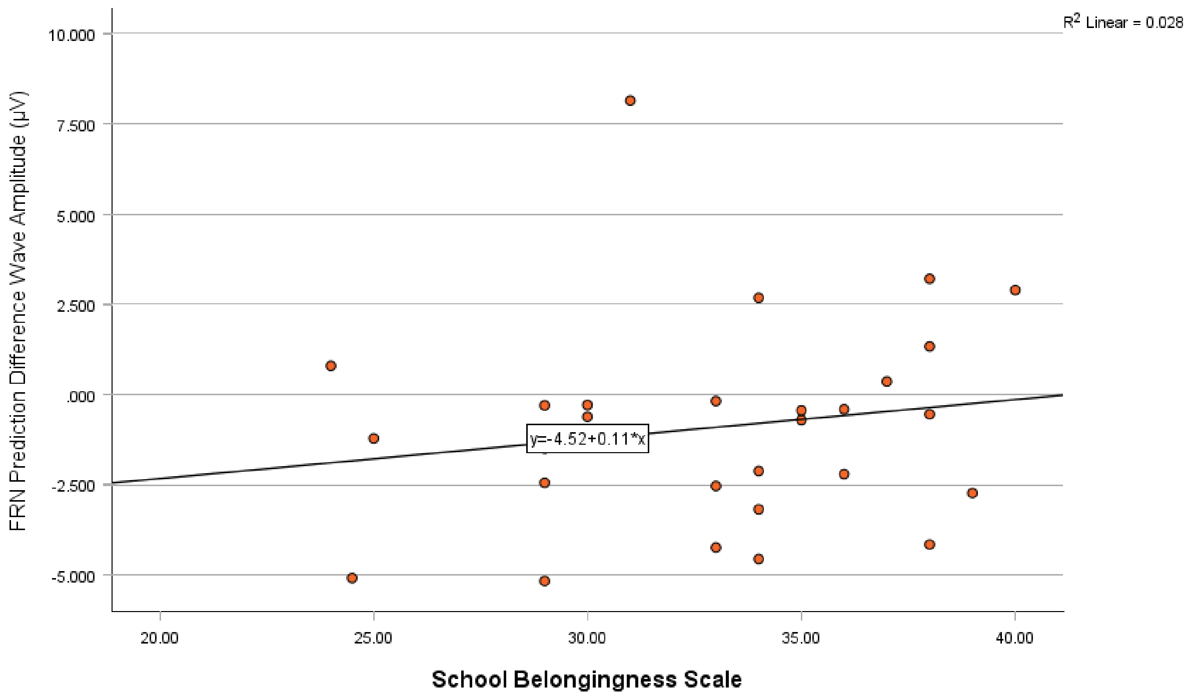


Figure 4.6.4.17 Correlation between SBS and the FRN prediction difference amplitude

In summary, the model revealed two significant main effects in the FRN: Prediction Valence and Electrode, and one significant interaction effect: Prediction Valence x NTS. Additionally, it showed a marginally significant interaction effect: Prediction Valence x SBS.

4.6.5 P3a

The P300 component, also known as the *P3*, encompasses several distinguishable ERP components (see Polich, 2012 for a review). The first major distinction of the P3 component was made by Squires and his colleagues (1975), who differentiated between an earlier frontal P3a component with a latency of about 240 ms and a later parietal P3 component with a mean latency of around 350 ms. They argued that these two subcomponents not only differed in their latency and scalp topography but also their psychological correlates (Squires et al., 1975). They believed that the P3a and P3b could be elicited by infrequent, unpredictable stimuli (Squires et al., 1975). Polich (2012) suggested that "the P300 may stem from neural inhibitory activity that enhances the attentional focus to promote memory storage" (p. 180). He argued that the P300 was "comprised of a P3a that results from an early attention-related process stemming from a working memory representational change, and P3b occurs when the attention-driven stimulus signal is transmitted to temporal and parietal structures (Polich, 2012, p. 180). In Polich (2007), it is reiterated that "it is reasonable to infer that stimulus evaluation engages *focal attention* (P3a) to facilitate context maintenance (P3b), which is associated with *memory* operations" (p. 2134).

In the literature reporting the ERP findings from the SJP, P3 was often used to index the processing of social evaluative feedback (Van der Molen et al., 2014), and it has been found that P3 is sensitive to expected acceptance feedback in this paradigm (Kortink et al., 2018; van der Molen et al., 2018; van der Veen et al., 2014; van der Veen et al., 2016). In this field, many researchers have often used P3 to denote this component without making clear distinctions between P3a and P3b (Kortink et al., 2018; Van der Molen et al., 2014; van der Molen et al., 2018; van der Veen et al., 2016; Van der Veen et al., 2019). In terms of latency, various post-feedback time windows have been utilised, for instance, between 275 and 375 ms (Van der Veen et al., 2014); from 300 to 400 ms (van der Veen et al., 2016; Van der Veen et al., 2019); from 360 to 440 ms (Van der Molen et al., 2014); or between 360 and 460 ms (Kortink et al., 2018; van der Molen et al., 2018). In addition, they have overlooked the scalp topography distinction between P3a and P3b. These researchers refer to this component as P3, regardless of whether it is extracted from the frontal or posterior sites, such as Fz, Cz, and Pz (Van der Veen et al., 2014; Van der Veen et al., 2019; van der Veen et al., 2016); just Pz (Van der Molen et al., 2014); or merely Fz (Kortink et al., 2018; van der Molen et al., 2018).

In contrast, some researchers distinguished between P3a and P3b in their studies when reporting ERPs from the SJP (Dekkers et al., 2015; Gu et al., 2020). However, not all these researchers acknowledged the difference in latency and scalp topography between P3a and P3b. For example, Dekkers and his colleagues (2015) identified the distinct latencies of P3a and P3b by defining the early P3 as occurring within the 280–500 ms post-feedback interval, while the late P3 occurred within the 425–650 ms post-feedback window. However, they obtained the early and late P3 from the same sites, including C3, Cz, C4, P3, Pz, P4, O1, Oz, and O2 (Dekkers et al., 2015). A recent study using the SJP made a clear distinction between the P3a and P3b components regarding their variations in scalp topography and latency (Gu et al., 2020). In this analysis, the frontal P3a (300–450 ms) was defined as the average amplitude post-feedback at the Fz, FC1, and FC2 electrodes, while the parietal P3b (500–650 ms) was defined as the average amplitude post-feedback at the electrode sites of P3, P4, Pz, CP1, and CP2 (Gu et al., 2020).

Drawing on previous literature that used the same paradigm, the current study clearly distinguished between a frontally maximal P3a and a parietally maximal P3b. The P3a (280-500 ms) was extracted from two frontal sites (e.g., Fz and Cz), while the P3b was extracted from three parietal sites (e.g., P3, P4, and Pz). The amplitudes of P3a and P3b were determined by calculating the mean amplitude of a positive deflection from 280 to 500 ms and 425 to 650 ms, respectively.

Prediction Valence and the P3a

The preliminary visual inspection of the grand averaged waveforms indicated that the P3a amplitude for No Prediction was more pronounced than that for Yes Prediction at both Fz and Cz (see Figure 4.6.5.1).

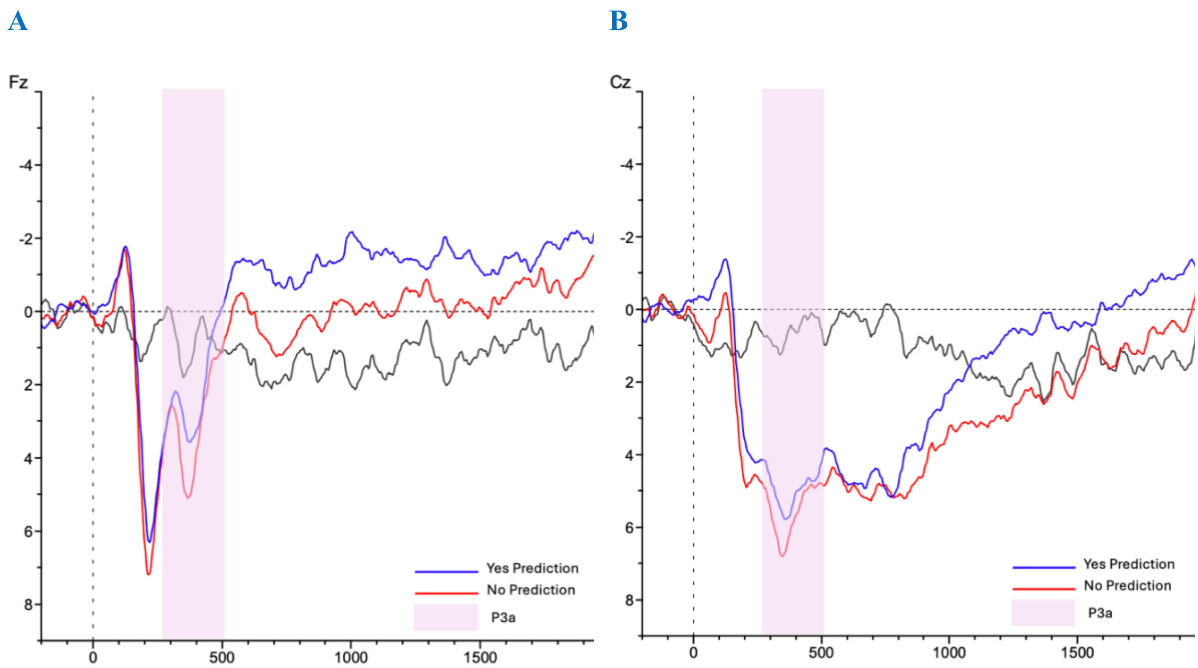


Figure 4.6.5.1 P3a grand averaged waveforms by Prediction Valence

Note: The figures show grand averaged waveforms from two conditions: Yes Prediction (in blue) and No Prediction (in red), extracted from the Fz (A) and Cz (B) channels. They illustrate the P3a wave occurring between 280 ms and 500 ms, as highlighted, after the onset of feedback stimuli, *Prediction Valence* The statistical analysis revealed that the main effect of Prediction Valance did not achieve significance: F (1, 180) = .277, p = .559. As illustrated in Figure 4.6.5.2, the P3a for No Prediction (M = 8.400, SE = .624) was greater than the P3a for Yes Prediction (M = 7.445, SE = .624); however, this difference was not significant.

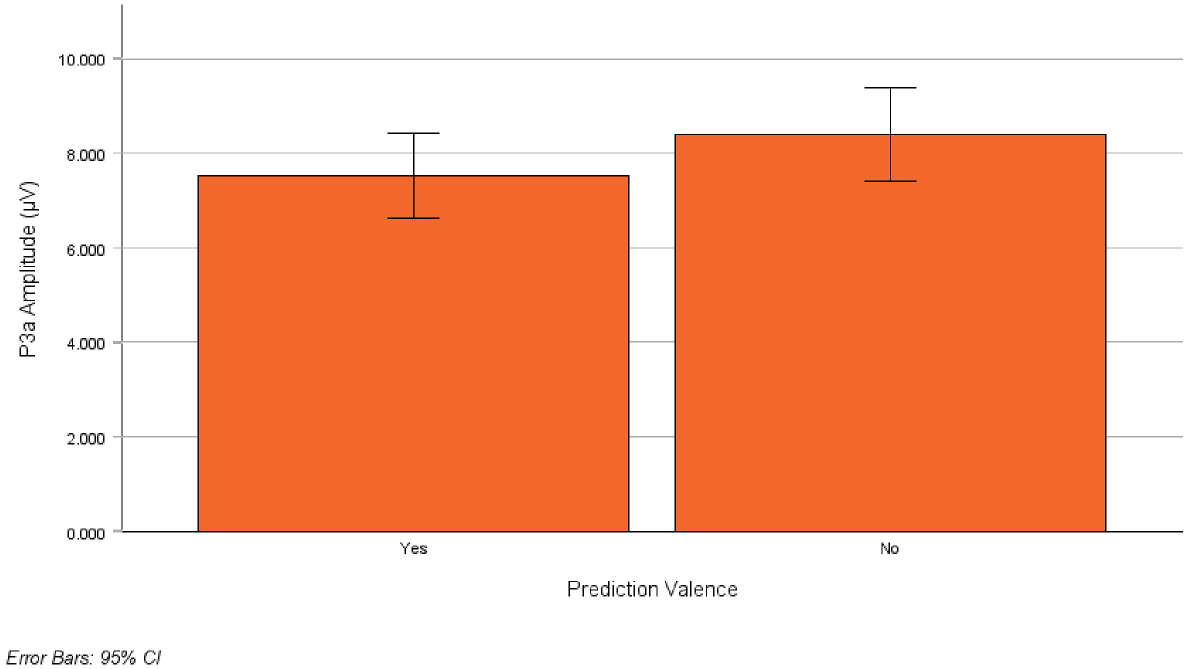


Figure 4.6.5.2 Averaged P3a amplitudes by Prediction Valence

Prediction Valence and the P3a Electrodes There was no significant interaction effect between Prediction Valence and the P3a Electrodes on the P3a amplitudes, F (1, 180) = .036, p = .850. None of the differences illustrated in Figure 4.6.5.3 were significantly different.

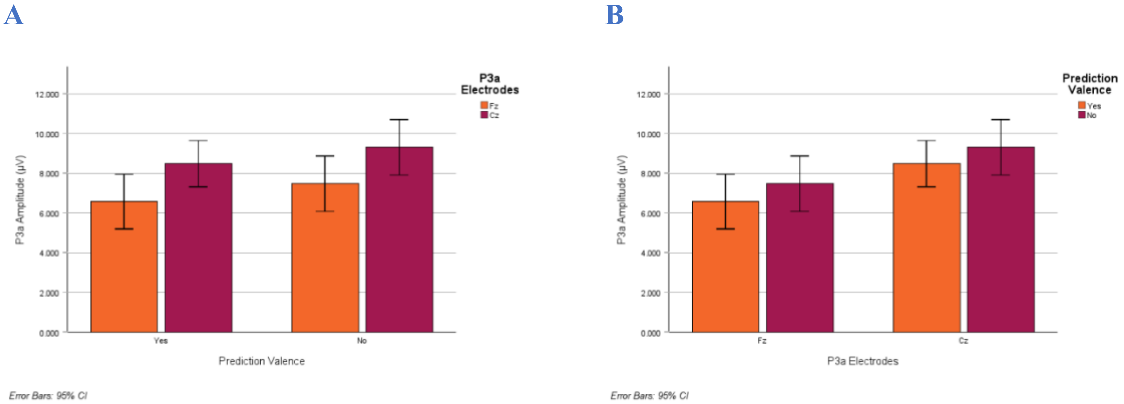


Figure 4.6.5.3 Averaged P3a amplitudes by Prediction Valence and the electrodes

Feedback Valence and the P3a

The preliminary visual inspection of the grand averaged waveforms revealed that the P3a amplitude for Yes Feedback was more pronounced than that for No Feedback at both Fz and Cz. This difference was more substantial at Cz compared to Fz. The statistical analysis discussed below confirmed these observations.

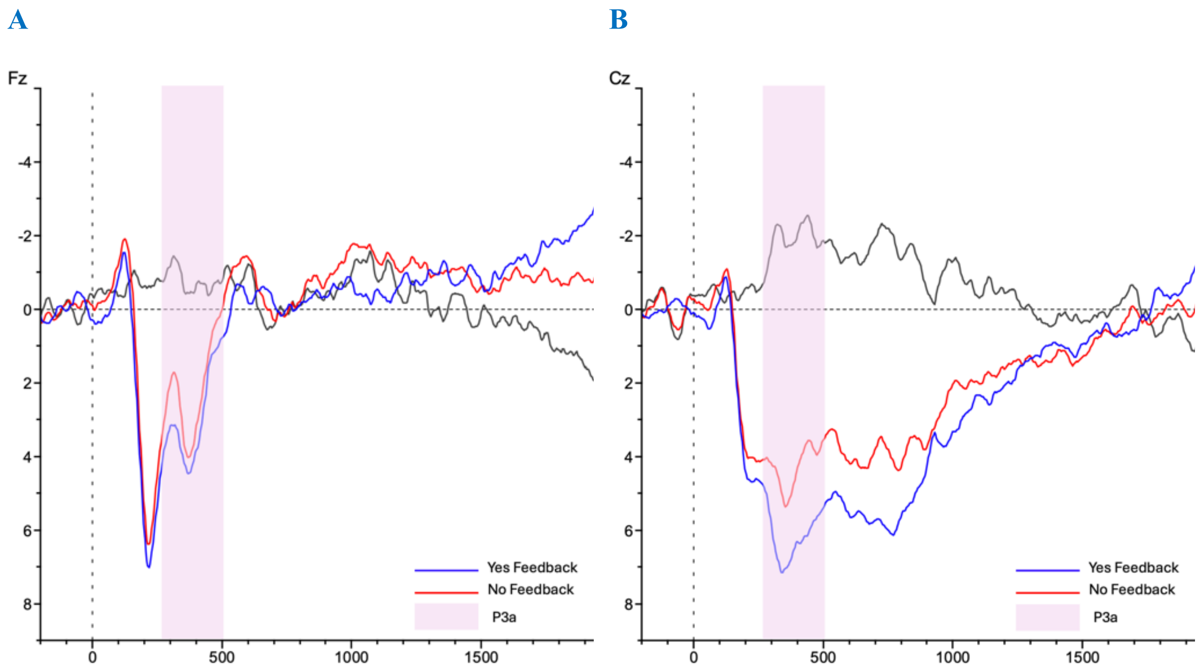


Figure 4.6.5.4 P3a grand averaged waveforms by Feedback Valence

Note: The figures illustrate grand averaged waveforms from two conditions: Yes Feedback (in blue) and No Feedback (in red), extracted from the Fz (A) and Cz (B) channels. They depict the P3a occurring between 280 ms and 500 ms, as highlighted, after the onset of the feedback stimuli, indicated as 0.

Feedback Valence The model showed no main effect of Feedback Valence, $F(1, 180) = 1.298$, $p = .256$. Additionally, Feedback Valence did not interact with any other predictors in the model. Nevertheless, the model's estimated marginal mean indicated a significant difference in P3a amplitude between Yes (M = 8.705, *SE* = .624) and No (*M* = 7.140, *SE* = .624) at Fz and Cz, with Yes Feedback exhibiting a higher amplitude than No Feedback, $|M_{diff}| = 1.566$, *SE* = .598, *df* = 180, $p = .010$, 95% CI [.386, 2.745] (see Figure 4.6.5.5). These P3a amplitude means for Feedback Valence were averaged across Fz and Cz.

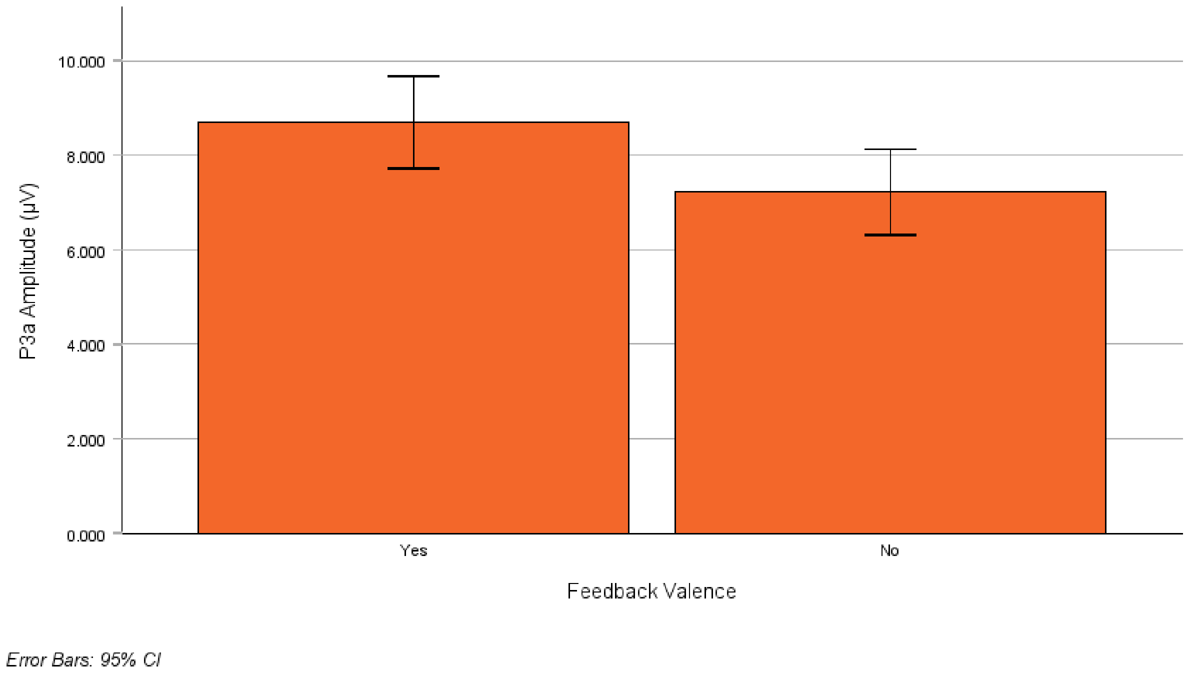


Figure 4.6.5.5 Averaged P3a amplitudes by Feedback Valence

Feedback Valence x *the P3a electrodes* There was no significant interaction effect between Feedback Valence and the P3a Electrodes on the P3a amplitudes, $F(1, 180) = .056$, $p = .814$.

Further pairwise comparisons separating the P3a at Fz and Cz revealed that the difference between feedback types primarily originated from Cz. When comparing Yes (*M* = 9.545, *SE* = .753) and No (*M* = 7.839, *SE* = .753) feedback, a significant difference in P3a amplitude was found at Cz, $|M_{diff}|$ = 1.706, SE = .844, *df* = 180, *p* = .045, 95% *CI* [.040, 3.372]; however, no significant difference was noted at Fz (see Figure 4.6.5.6A).

Furthermore, Figure 4.6.5.6B compares the P3a between Fz and Cz separately for both Yes and No Feedback. The difference between Fz (*M* = 7.865, *SE* = .753) and Cz (*M* = 9.545, *SE* = .753) was statistically significant for Yes Feedback, $|M_{diff}|$ = 1.679, *SE* = .843, *df* = 180, *p* = .048, 95% *CI* [-3.343, -.016], but not for No Feedback. Figure 4.6.5.7 presents the grand average topographical maps of the P3a for Yes Feedback (A) and No Feedback (B).

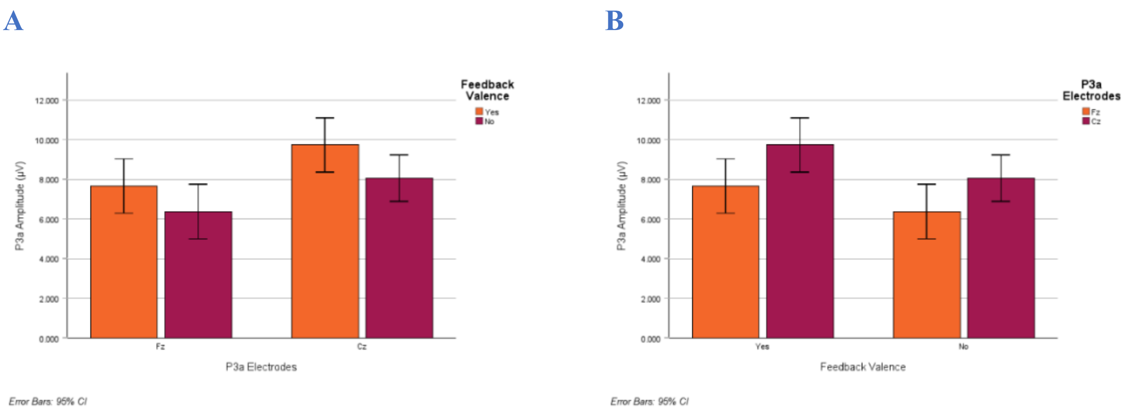


Figure 4.6.5.6 Averaged P3a amplitudes by Feedback Valence and the electrodes

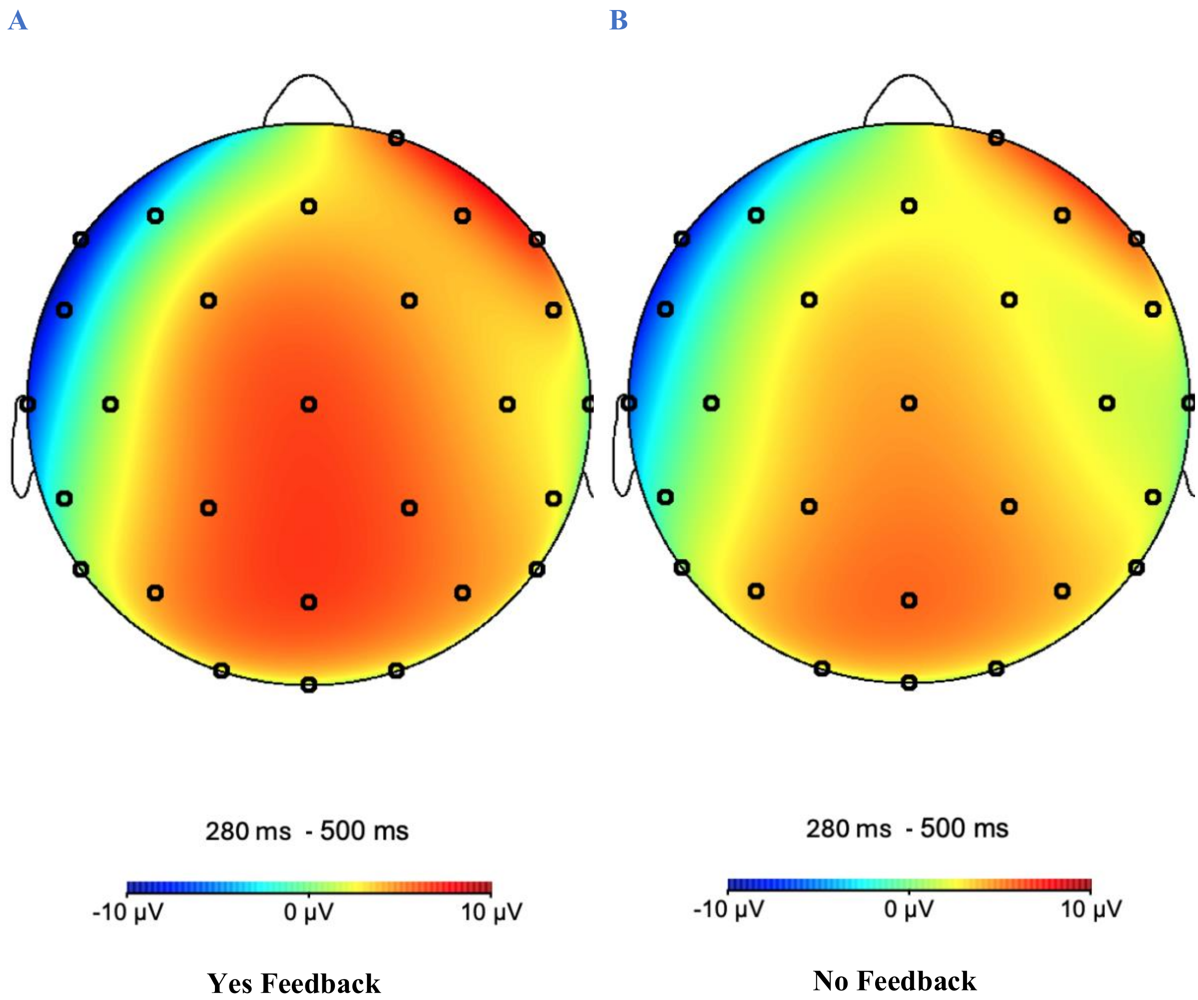


Figure 4.6.5.7 Grand average topographical maps of the P3a

Congruency and the P3a

The preliminary visual inspection of the grand averaged waveforms indicated that the P3a amplitude for unexpected acceptance (NY) was the most pronounced, followed by the P3a for expected acceptance (YY) (see Figure 4.6.5.8). The smallest P3a amplitude was clearly for unexpected rejection (YN) (see Figure 4.6.5.8). These patterns were consistent across both Fz and Cz channels, although the smallest P3a amplitude at Fz was less obvious than that at Cz (see Figure 4.6.5.8).

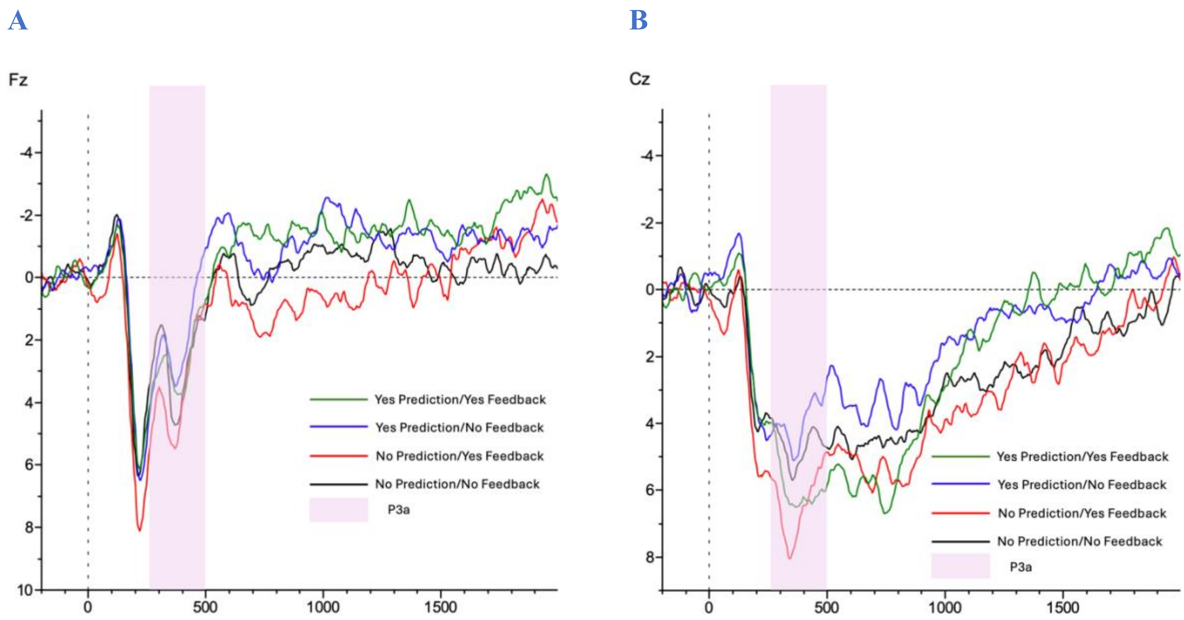


Figure 4.6.5.8 P3a grand averaged waveforms by congruency type

Note: The figures depict the grand averaged waveforms for four contingency conditions: YY (in green), YN (in blue), NY (in red), and NN (in black), extracted separately from the Fz (A)and Cz (B) channels. They illustrate the P3a occurring between 280 ms and 500 ms, as highlighted, after the onset of feedback stimuli, indicated as 0.

Congruency Although averaged amplitudes are consistent with the observations above (see Figure 4.6.5.9), the statistical test did not reach a significant level. Firstly, no significant two-way interaction effect between Prediction Valence and Feedback Valence in P3a was found, F (1, 180) = .088, p = .767. Nevertheless, as shown in Figure 4.6.5.9, the model estimated marginal means indicated that the P3a difference between unexpected rejection (YN) (M = 6.617, SE = .754) and unexpected acceptance (NY) (M = 9.318, SE = .754) was statistically significant, $|M_{diff}|$ = 2.521, SE = .845, df = 180, p = .019, 95% CI [-4.770, -.272]. These means were averaged across Fz and Cz. This was the only significant difference among the four congruency types (see Figure 4.6.5.9).

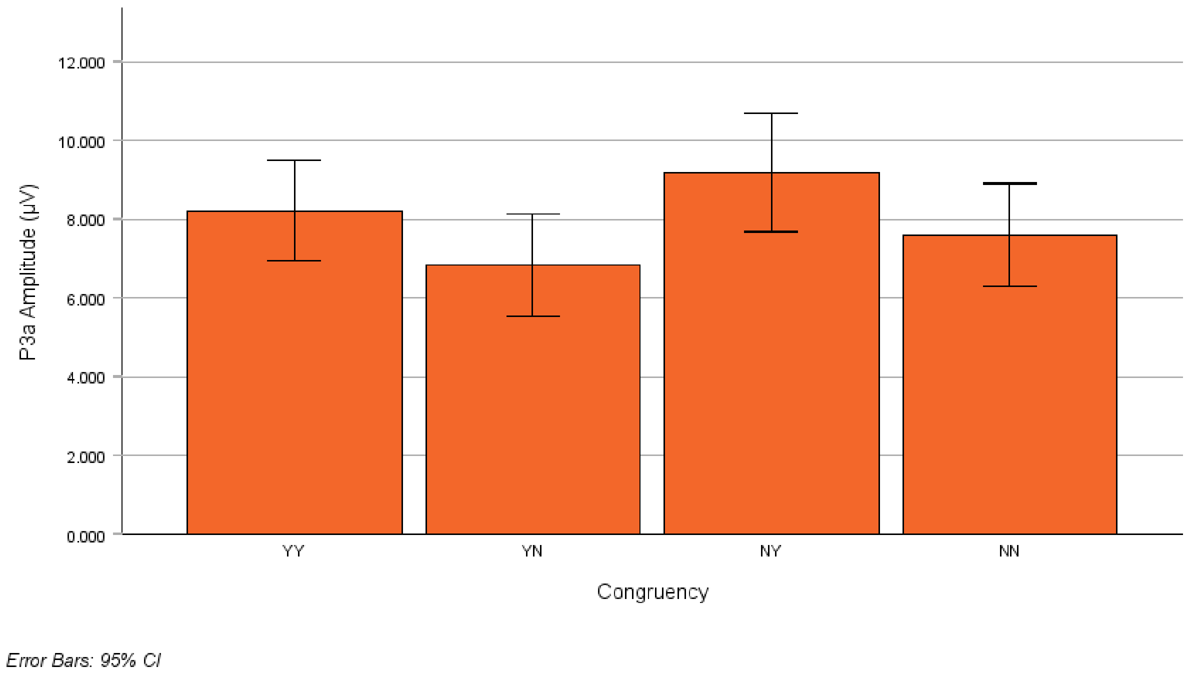


Figure 4.6.5.9 Averaged P3a amplitudes by congruency type

Congruency x *the P3a electrodes* The interaction effect between congruency and the P3a electrodes was not significant, F (1, 180) = .343, p = .559. None of the differences in Figure 4.6.5.10 were significant.

A **B**

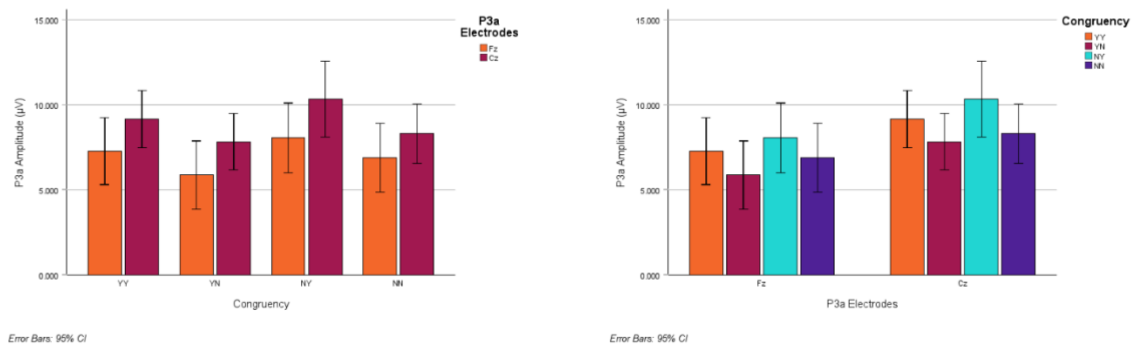


Figure 4.6.5.10 Averaged P3a amplitudes by congruency type and the electrodes

Gender and the P3a

Gender No significant main effect of gender was found, F (1, 24.013) = 2.577, p = .122. As shown in Figure 4.6.5.11, the P3a difference between genders was not significant.

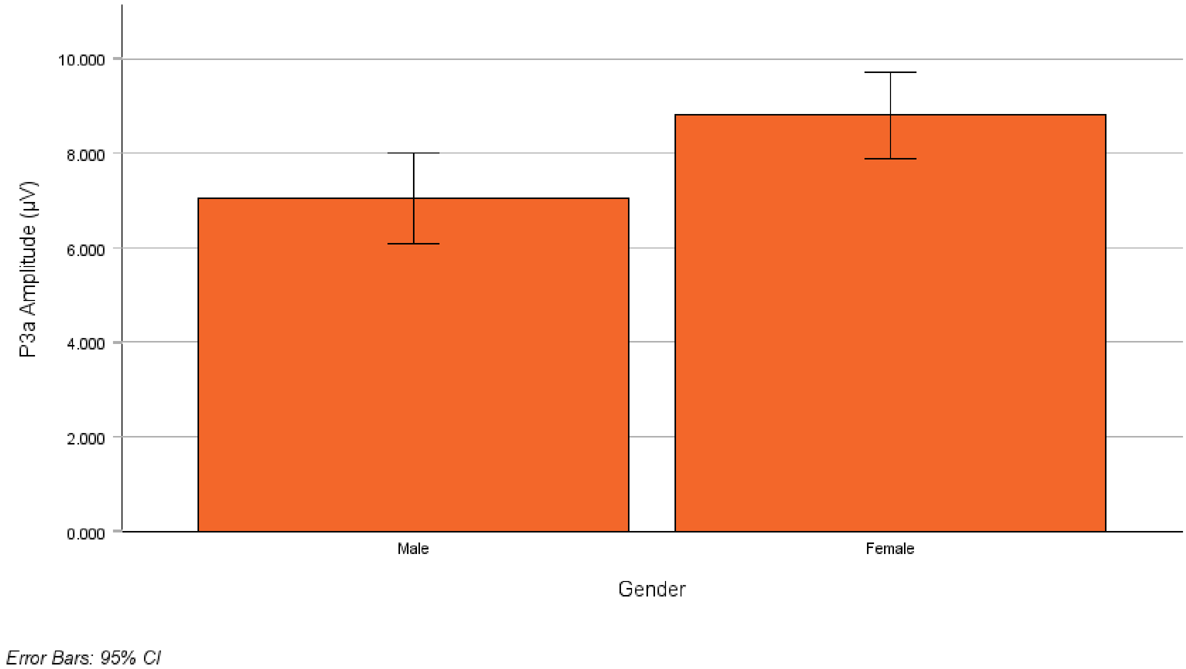


Figure 4.6.5.11 Averaged P3a amplitudes by gender

Gender x *Prediction Valence* There was no significant interaction effect between gender and Prediction Valence, F (1, 180) = .018, p = .893. None of the differences illustrated in Figure 4.6.5.12 were significant.

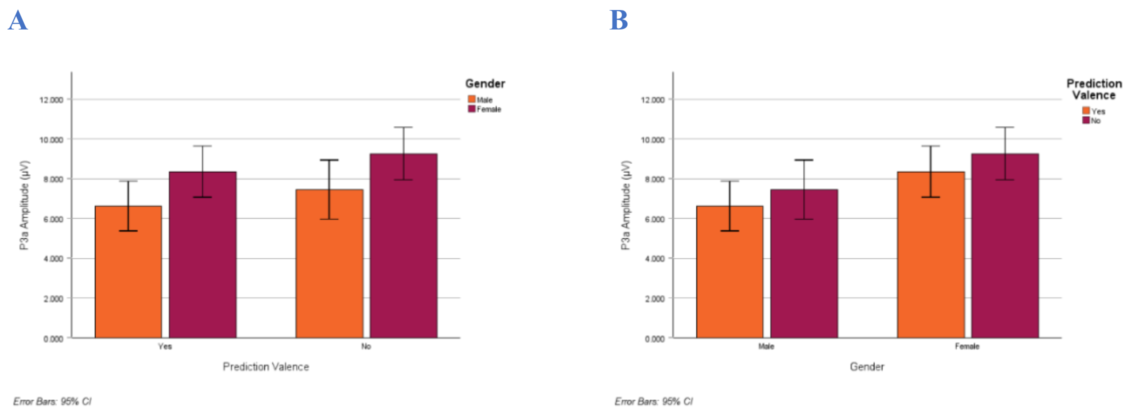


Figure 4.6.5.12 Averaged P3a amplitudes by gender and Prediction Valence

Gender x *Feedback Valence* There was no significant interaction effect of Gender x Feedback Valence, F (1, 180) = 1.950, p = .164. Controlling for Feedback Valence, a statistically significant gender difference emerged for No Feedback, where girls (M = 8.485, SE = .865) exhibited a larger P3a than boys (M = 5.795, SE = .932), $|M_{diff}|$ = 2.690, SE = 1.295, df = 39.993, p = .044, 95% CI [.074, 5.307]. The P3a gender difference between girls (M = 9.184, SE = .865) and boys (M = 8.226, SE = .932) for Yes Feedback was not significant, $|M_{diff}|$ = .957, SE = 1.295, df = 39.993, p = .464, 95% CI [-1.659, 3.574] (see Figure 4.6.5.13A).

Figure 4.6.5.13B compares the P3a between Yes and No Feedback across genders. A significant difference in P3a was found between Yes (M = 8.226, SE = .932) and No (M = 5.795, SE = .932) feedback only for the boys, $|M_{diff}|$ = 2.432, SE = .893, df = 180, p = .007, 95% CI [.670, 4.194] (refer to Figure 4.6.5.13B). No significant difference in P3a was observed between Yes and No Feedback for the girls.

A B

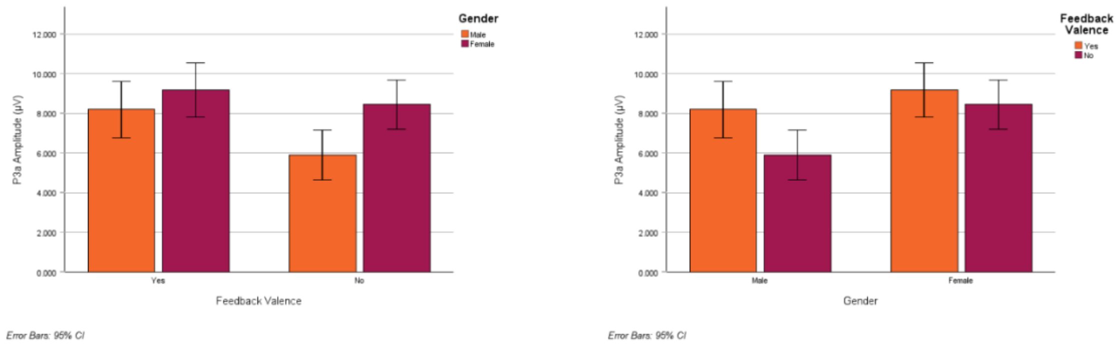


Figure 4.6.5.13 Averaged P3a amplitudes by gender and Feedback Valence

Gender x *Congruency* There was no significant interaction effect of Gender x Congruency, F (1, 180) = .021, p = .886. Figure 4.6.5.14A compares the P3a amplitudes for four congruency types within each gender, while Figure 4.6.5.14B illustrates the gender differences across each congruency type. A marginally significant difference was observed between unexpected rejection (YN) (M = 5.270, SE = 1.125) and unexpected acceptance (NY) (M = 8.573, SE = 1.125) for the boys, with the P3a for unexpected acceptance (NY) being larger than for unexpected rejection (YN), $|M_{diff}|$ = 3.304, SE = 1.263, df = 180, p = .057, 95% CI [-6.663, .056] (refer to Figure 4.6.5.14A). No other differences depicted in Figure 4.6.5.14 were statistically significant.

A B

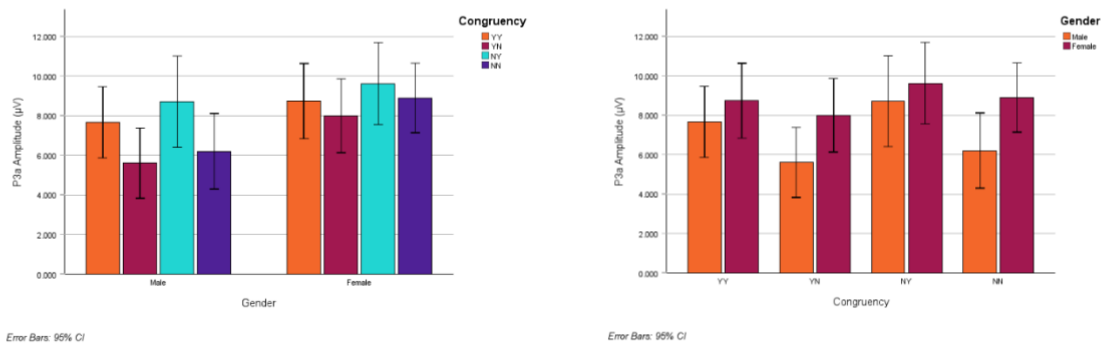


Figure 4.6.5.14 Averaged P3a amplitudes by gender and congruency

Electrode and the P3a The electrode was a significant predictor of the P3a amplitude, F (1, 180) = 6.660, p = .011. No interaction effect was found between the electrodes and other predictors in the model. The model's estimated marginal mean suggested that the P3a at Cz (M = 8.692, SE = .623) was statistically significantly larger than the P3a at Fz (M = 7.153, SE = .623), $|M_{diff}|$ = 1.539, SE = .596, df = 180, p = .011. 95% CI [.362, 2.715]. (see Figure 4.6.5.15).

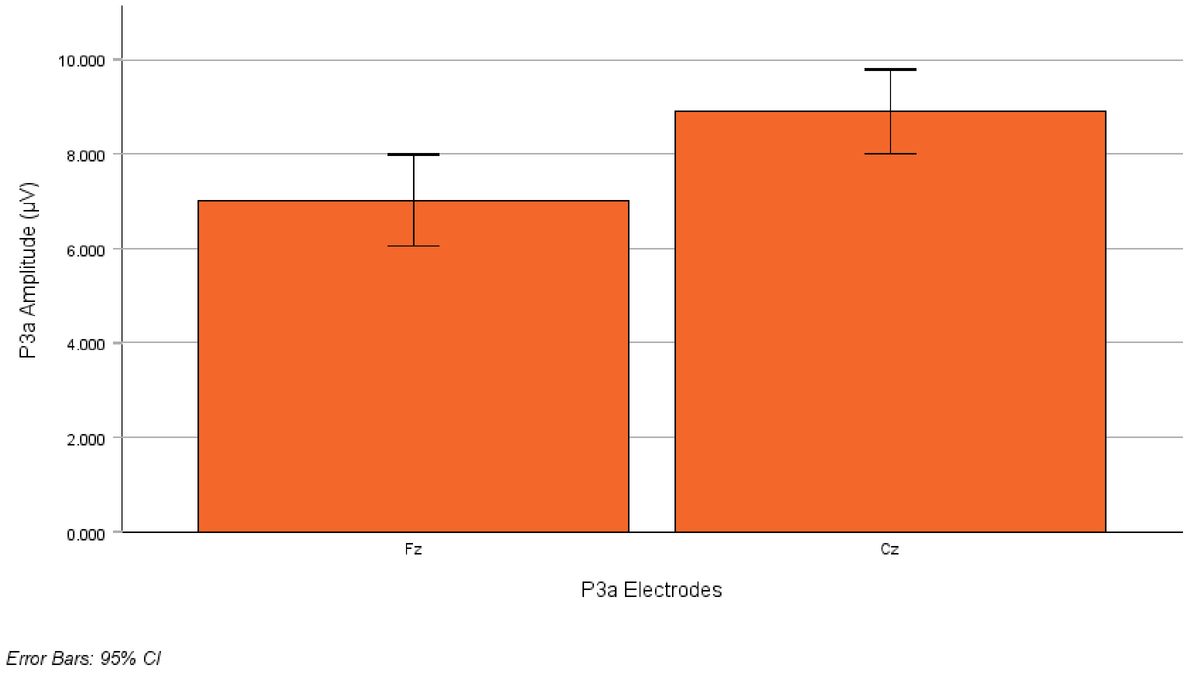


Figure 4.6.5.15 Averaged P3a amplitudes by the electrodes

4.6.6 P3b

The mean amplitude of a positive deflection during the 425-650 ms post-feedback window was extracted at P3, Pz, and P4 and quantified as P3b.

Prediction Valence and the P3b

The preliminary visual inspection of the grand waveforms for Yes and No Prediction indicated that the P3b amplitude was greater for No Prediction than for Yes Prediction at the Pz and P3 channels. The difference in P3b for Yes and No Prediction at P4 was less pronounced.

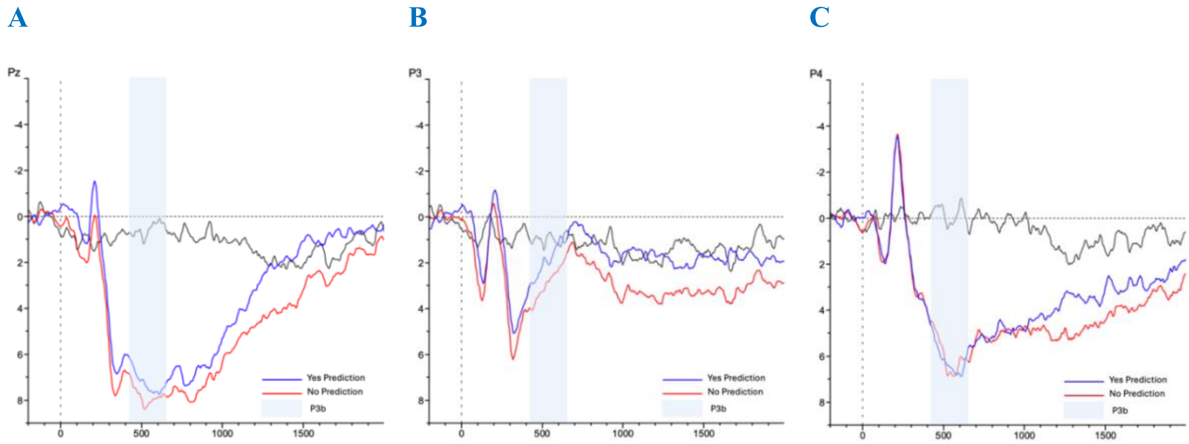


Figure 4.6.6.1 P3b grand averaged waveforms by Prediction Valence

Note: The figures show grand averaged waveforms from two conditions: Yes Prediction (in blue) and No Prediction (in red), extracted separately from the Pz (A), P3 (B), and P4 (C) channels. They illustrate the P3b occurring between 425 ms and 650 ms, as highlighted, after the onset of feedback stimuli, indicated as 0.

Prediction Valence Statistical analysis indicated no significant main effect of Prediction Valence on P3b amplitude, $F(1, 288.001) = .185$, $p = .667$. The P3b difference shown in Figure 4.6.6.2 was not statistically significant.

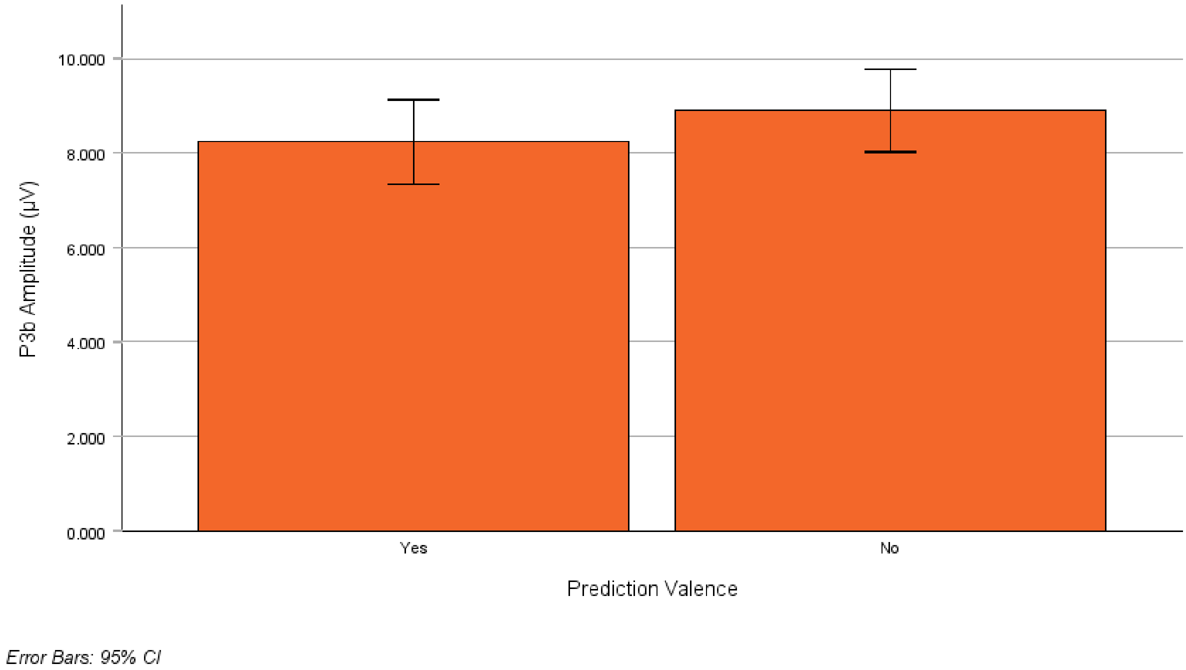


Figure 4.6.6.2 Averaged P3b amplitudes by Prediction Valence

Prediction Valence x the P3b Electrodes There was no significant interaction effect between Prediction Valence and the P3b electrodes, F (2, 288.001) = .199, p = .820. However, as shown in Figure 4.6.6.3A and Table 4.6.6.1, the P3b differences between Pz and P3, as well as between P4 and P3, were statistically significant for both Yes and No Predictions. Nevertheless, the P3b difference between Pz and P4 did not achieve significance for either Yes or No Prediction. None of the differences depicted in Figure 4.6.6.3B were statistically significant.

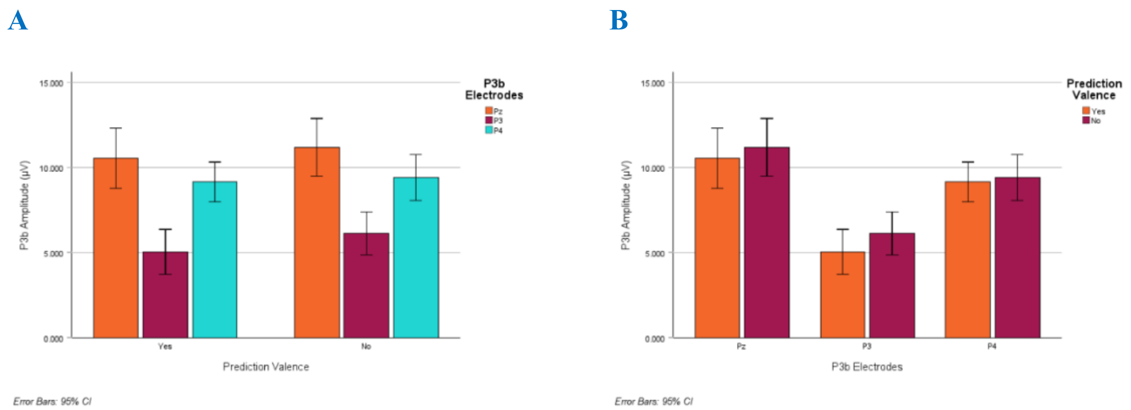


Figure 4.6.6.3 Averaged P3b amplitudes by Prediction Valence and the electrodes

Table 4.6.6.1 Pairwise comparisons among the P3b electrodes and Prediction Valence

Prediction Valence	(I) P3b Electrode	(J) P3b Electrode	Mean Difference (I-J)	Std. Error	*df*	*Sig.*[c]	95% Confidence Interval for Difference[c] Lower Bound	Upper Bound
Yes	Pz	P3	5.047*	.767	288.001	<.001	3.206	6.889
	Pz	P4	1.199	.767	288.001	.316	-.642	3.041
	P3	P4	-3.848*	.767	288.001	<.001	-5.690	-2.006
No	Pz	P3	4.798*	.767	288.001	<.001	2.957	6.640
	Pz	P4	1.627	.767	288.001	.101	-.215	3.468
	P3	P4	-3.172*	.767	288.001	<.001	-5.013	-1.330

Feedback Valence and the P3b

The preliminary visual inspection of the grand waveforms for Yes and No Feedback showed little P3b amplitude difference between them at Pz, P3, and P4 (see Figure 4.6.6.4).

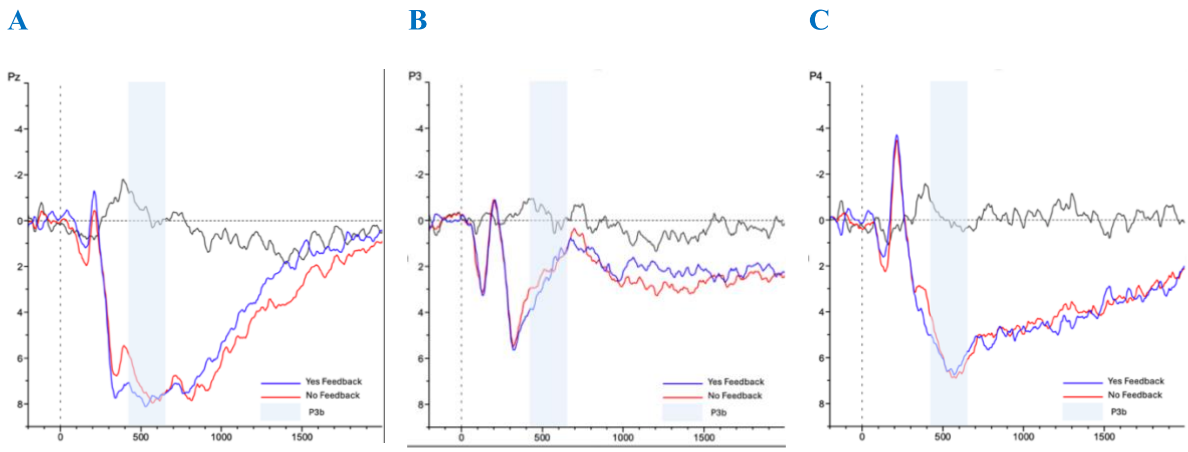


Figure 4.6.6.4 P3b grand averaged waveforms by Feedback Valence

Note: The figures depict grand averaged waveforms from two conditions: Yes Feedback (in blue) and No Feedback (in red), extracted separately from the Pz (A), P3 (B), and P4 (C) channels. They show the P3b between 425 ms and 650 ms, as highlighted, after the onset of feedback stimuli, indicated as 0.

Feedback Valence The statistical analysis corroborated the observation above and found no significant effect of Feedback Valence on the P3b amplitude: *F* (1, 288.001) = .151, *p* = .698. As depicted in Figure 4.6.6.5, the P3b difference between Yes and No Feedback was minimal when averaged across the channels. Figure 4.6.6.6 illustrates the grand average topographical of the P3b for Yes Feedback (A) and No Feedback (B).

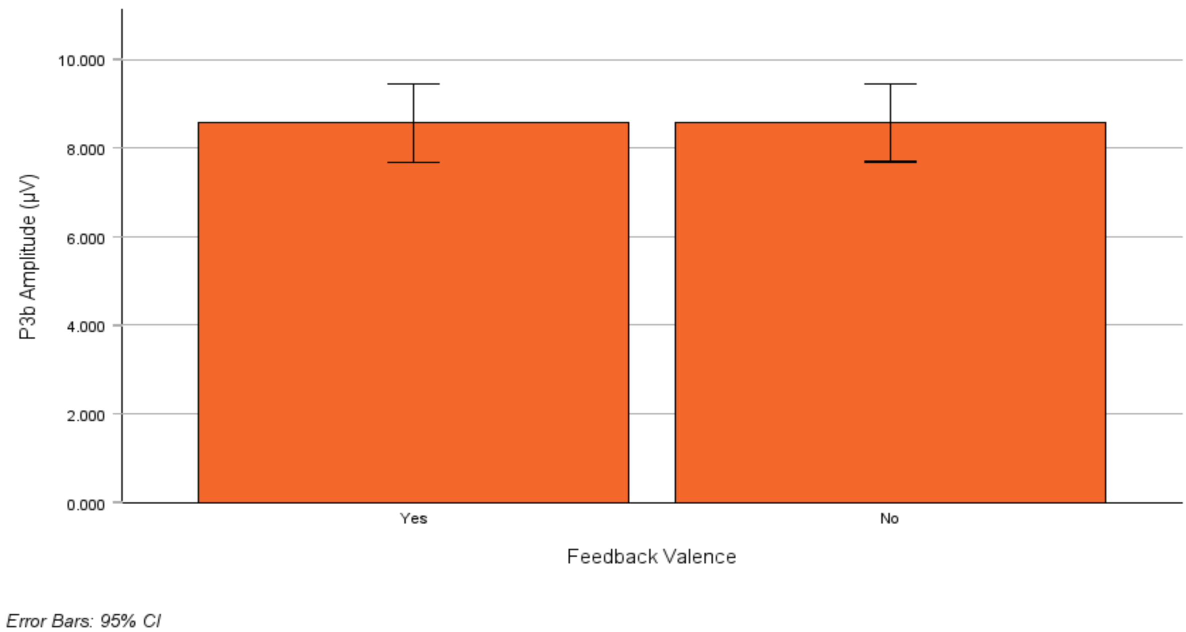


Figure 4.6.6.5 Averaged P3b amplitudes by Feedback Valence

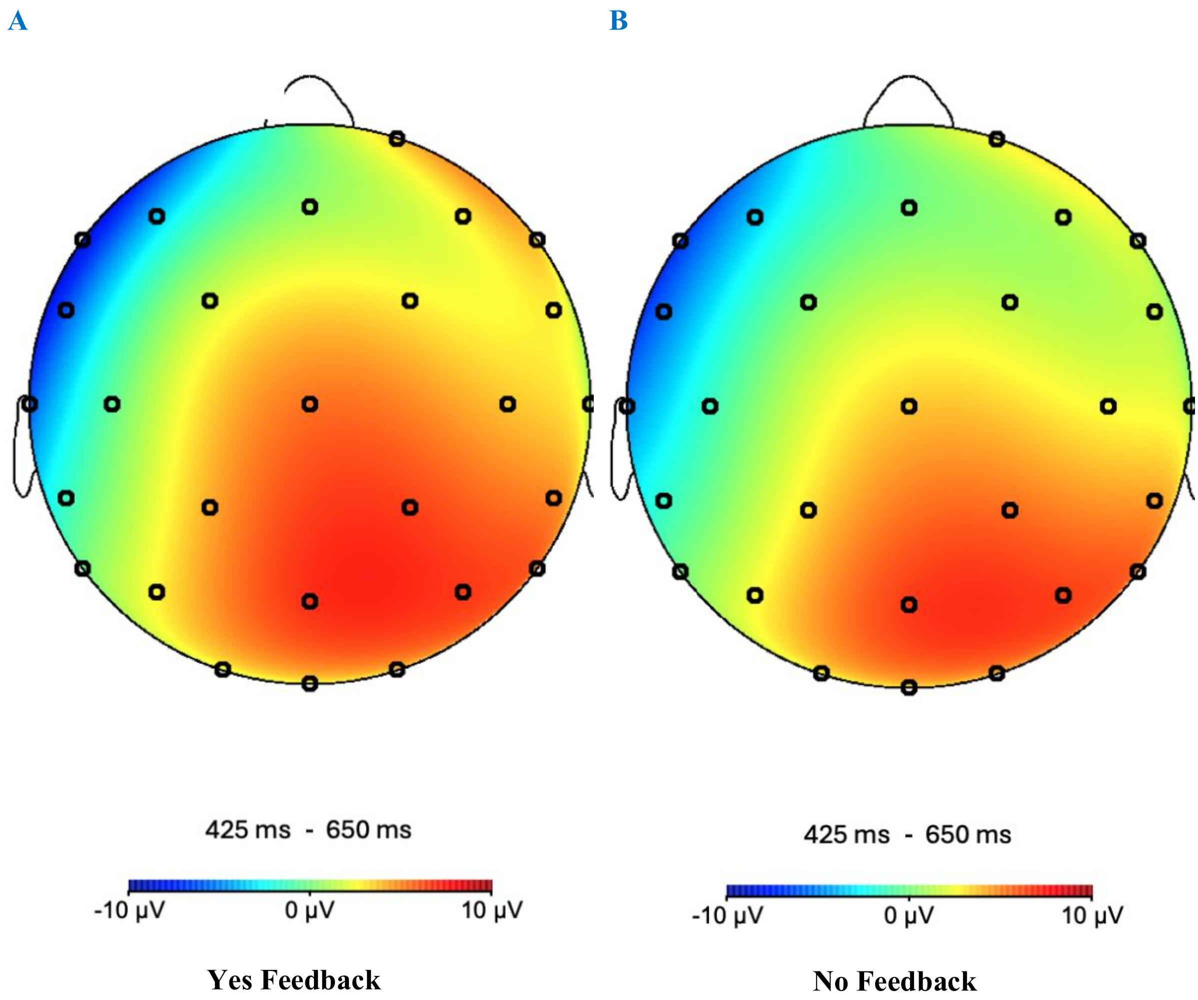


Figure 4.6.6.6 Grand average topographical maps of the P3b

Feedback Valence x *the P3b Electrodes* There was no significant interaction effect between Feedback Valence and the P3b electrodes, F (2, 288.001) = .070, p = .933. As illustrated in Figure 4.6.6.7A and Table 4.6.6.2, the P3b differences between Pz and P3, as well as between P4 and P3, were statistically significant for both Yes and No Feedback. However, the P3b difference between Pz and P4 did not reach significance for either Yes or No Feedback (see Table 4.6.6.2). None of the differences shown in Figure 4.6.6.7B were statistically significant.

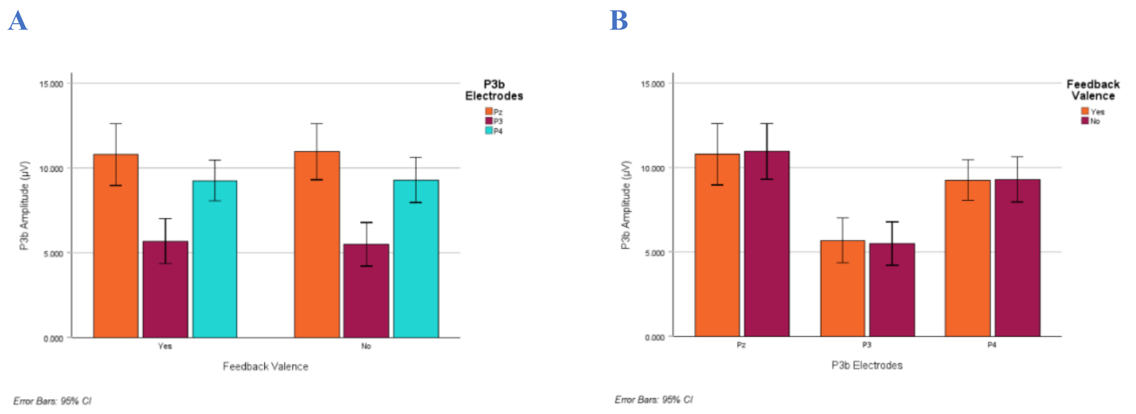


Figure 4.6.6.7 Averaged P3b amplitudes by Feedback Valence and the electrodes

Table 4.6.6.2 Pairwise comparisons among the P3b electrodes and Feedback Valence

Feedback Valence	(I) P3b Electrode	(J) P3b Electrode	Mean Difference (I-J)	Std. Error	*df*	*Sig.*[c]	95% Confidence Interval for Difference[c] Lower Bound	Upper Bound
Yes	Pz	P3	4.722*	.767	288.001	<.001	2.880	6.563
	Pz	P4	1.332	.767	288.001	.230	-.510	3.174
	P3	P4	-3.390*	.767	288.001	<.001	-5.232	-1.548
No	Pz	P3	5.124*	.767	288.001	<.001	3.282	6.966
	Pz	P4	1.494	.767	288.001	.149	-.348	3.336
	P3	P4	-3.630*	.767	288.001	<.001	-5.472	-1.788

Congruency and the P3b

The preliminary visual inspection of the grand waveforms for four contingency categories revealed distinct patterns at the Pz, P3, and P4 channels (Figure 4.6.6.8). At the P3 channel, the P3b for unexpected acceptance (NY) was the largest. The P3b differences among the four contingency categories were less evident at the Pz and P4 channels.

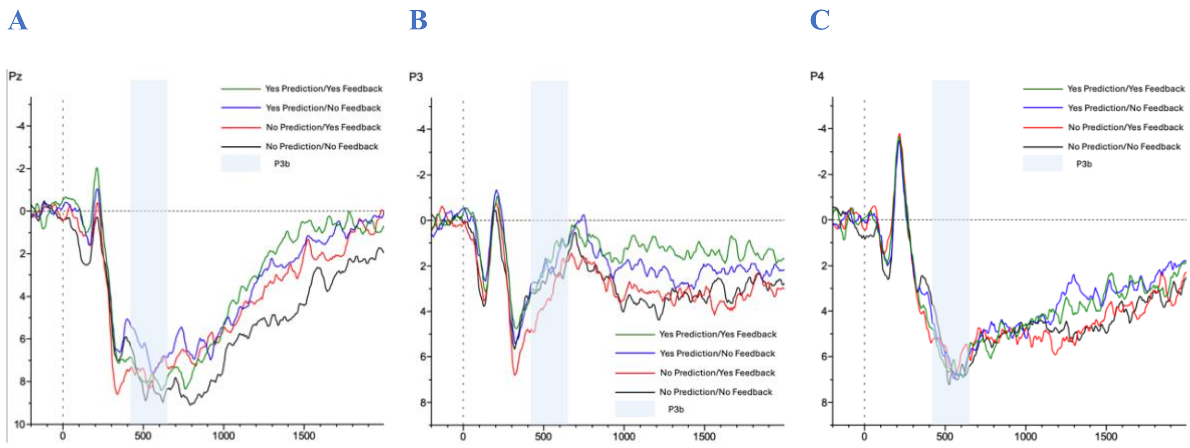


Figure 4.6.6.8 P3b grand averaged waveforms by congruency type

Note: The figures illustrate the grand averaged waveforms from four contingency conditions: YY (in green), YN (in blue), NY (in red), and NN (in black), extracted separately from the Pz (A), P3 (B), and P4 (C) channels. They show the P3b occurring between 425 ms and 650 ms, as highlighted, after the onset of feedback stimuli, indicated as 0.

Congruency Statistical analysis confirmed the preceding observations and identified no significant effect of congruency on P3b, $F(1, 288.001) = .020$, $p = .888$. As illustrated in Figure 4.6.6.9, none of the comparisons among these types were statistically significant.

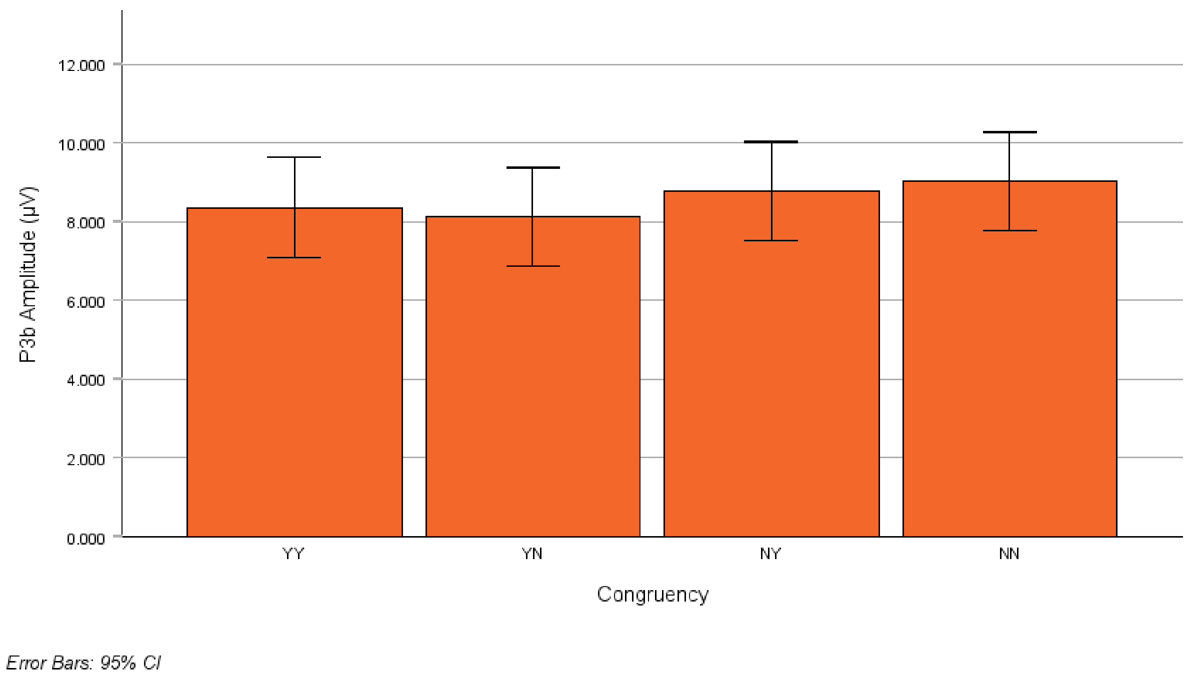


Figure 4.6.6.9 Averaged P3b amplitudes by congruency type

Congruency x *the P3b electrodes* The interaction between congruency and the P3b Electrode was not significant, F (2, 288.001) = 1.932, p = .147 (see Figure 4.6.6.10). Figure 4.6.6.10A compares the P3b amplitudes for each congruency type among Pz, P3, and P4. As shown in Table 4.6.6.3, significant P3b differences were found between Pz and P3, as well as between P4 and P3 for all four congruency types. A significant P3b difference was observed between Pz and P4 only for expected rejection (NN). None of the differences illustrated in Figure 4.6.6.10B were statistically significant.

A B

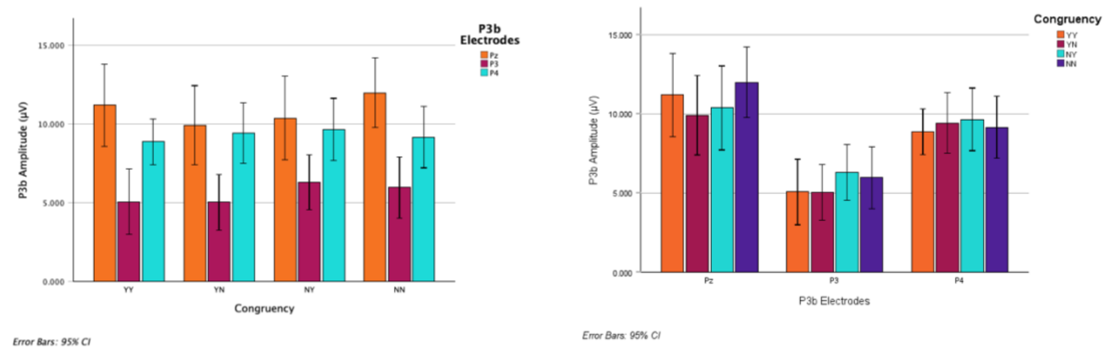


Figure 4.6.6.10 Averaged P3b amplitudes by congruency type and the electrodes

Table 4.6.6.3 Pairwise comparisons between the P3b electrodes for each congruency type

Congruency	(I) P3b Electrodes	(J) P3b Electrodes	Mean Difference (I-J)	Std. Error	*df*	*Sig.*[c]	95% Confidence Interval for Difference[c] Lower Bound	Upper Bound
YY	Pz	P3	5.644*	1.084	288.001	<.001	3.039	8.248
	Pz	P4	2.130	1.084	288.001	.144	-.475	4.734
	P3	P4	-3.514*	1.084	288.001	.004	-6.119	-.909
YN	Pz	P3	4.451*	1.084	288.001	<.001	1.847	7.056
	Pz	P4	.269	1.084	288.001	.992	-2.335	2.874
	P3	P4	-4.182*	1.084	288.001	<.001	-6.786	-1.577
NY	Pz	P3	3.800*	1.084	288.001	.002	1.195	6.404
	Pz	P4	.534	1.084	288.001	.946	-2.070	3.139
	P3	P4	-3.266*	1.084	288.001	.008	-5.870	-.661
NN	Pz	P3	5.797*	1.084	288.001	<.001	3.193	8.402
	Pz	P4	2.719*	1.084	288.001	.038	.115	5.324
	P3	P4	-3.078*	1.084	288.001	.015	-5.682	-.473

Gender and the P3b

Gender No main effect of gender was found, F (1, 24.019) = 3.041, p = .094, indicating no overall gender difference in the P3b amplitude (see Figure 4.6.6.11).

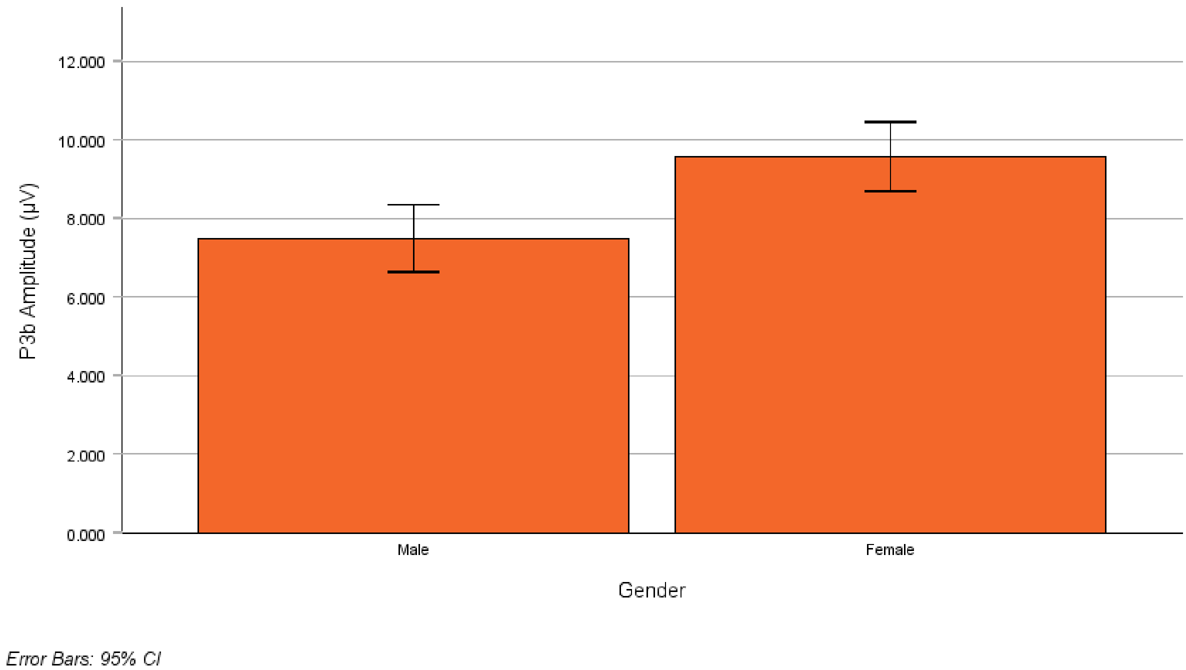


Figure 4.6.6.11 Averaged P3b amplitudes by gender

Gender x *Prediction Valence* There was a marginally significant interaction effect between gender and Prediction Valence, *F* (1, 288.001) = 3.418, *p* = .066. The estimated marginal means indicated that the P3b amplitude for the girls (*M* = 9.758, *SE* = 1.074) was greater than that of the boys (*M* = 6.221, *SE* = 1.157) when the Prediction Valence was positive. The pairwise comparison revealed that this gender difference for Yes Prediction was statistically significant, $|M_{diff}|$ = 3.537, *SE* = 1.607, *df* = 28.494, *p* = .036, 95% *CI* [.247, 6.826]. However, the P3b gender difference between the girls and boys for No Prediction was not significant, $|M_{diff}|$ = 1.833, *SE* = 1.607, *df* = 28.494, *p* = .263, 95% *CI* [-1.456, 5.123]. In other words, the gender difference primarily stemmed from Yes Prediction. To be more precise, this difference emerged because the boys exhibited a lower P3b after providing the Yes Prediction (see Figure 4.6.6.12A). As shown in Figure 4.6.6.12B, the P3b amplitudes for the girls were similar for both Yes and No Predictions. In contrast, there was a significant P3b difference between Yes (*M* = 6.221, *SE* = 1.157) and No (*M* = 7.906, *SE* = 1.157) predictions for the boys, $|M_{diff}|$ = 1.686, *SE* = .663, *df* = 288.001, *p* = .012, 95% *CI* [-2.991, -.381].

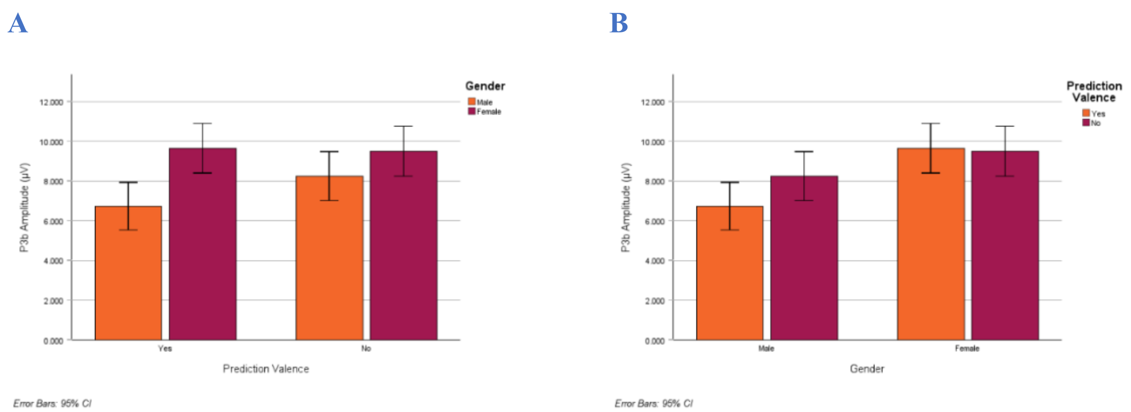


Figure 4.6.6.12 Averaged P3b amplitudes by gender and Prediction Valence

Gender x *Feedback Valence* There was no significant interaction effect between gender and Feedback Valence, *F* (1, 288.001) = .782, *p* = .377. However, as illustrated in Figure 4.6.6.13A, there was a marginally significant gender difference for Yes Feedback, where the girls (*M* = 9.933, *SE* = 1.074) exhibited a larger P3b than the boys (*M* = 6.841, *SE* = 1.157), $|M_{diff}|$ = 3.092, *SE* = 1.607, *df* = 28.494, *p* = .064, 95% *CI* [-.197, 6.382]. The P3b gender difference between the girls and boys for No Feedback was insignificant, $|M_{diff}|$ = 2.278, *SE* = 1.607, *df* = 28.494, *p* = .167, 95% *CI* [-1.012, 5.567]. In other words, the gender difference was primarily from Yes Feedback. Figure 4.6.6.13B shows the P3b differences between Yes and No Feedback within each gender, and none of these differences were statistically significant.

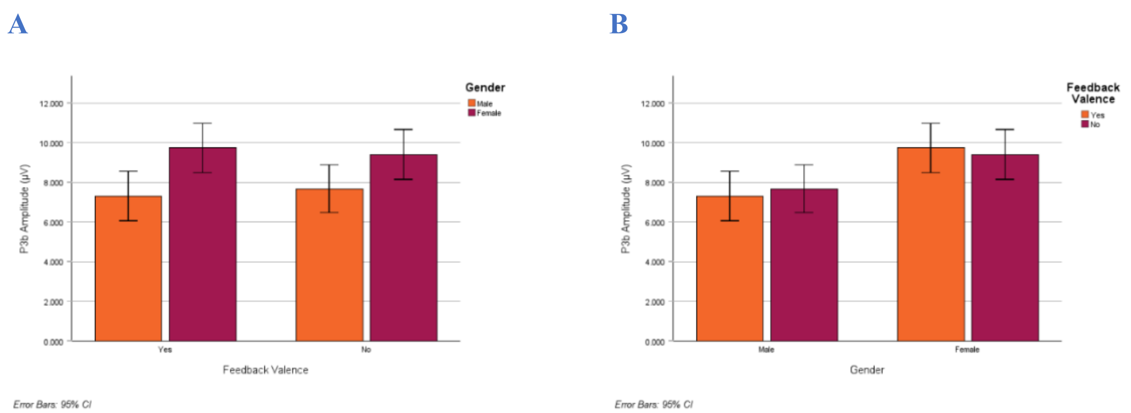


Figure 4.6.6.13 Averaged P3b amplitudes by gender and Feedback Valence

Gender x *Congruency* There was no significant interaction effect of Gender x Congruency, *F* (1, 288.001) = 1.459, *p* = .228. Figure 4.6.6.14A illustrates the gender differences across each congruency type, while Figure 4.6.6.14B compares the P3b amplitudes for four congruency types within each gender. There was only one significant difference between male (*M* = 5.838, *SE* = 1.248) and female (*M* = 10.338, *SE* = 1.159) for expected acceptance (YY), $|M_{diff}|$ = 4.501, *SE* = 1.734, *df* = 38.395, *p* = .013, 95% CI [-8.011, -.991] (refer to Figure 4.6.5.14A). No other differences depicted in Figure 4.6.5.14 were statistically significant.

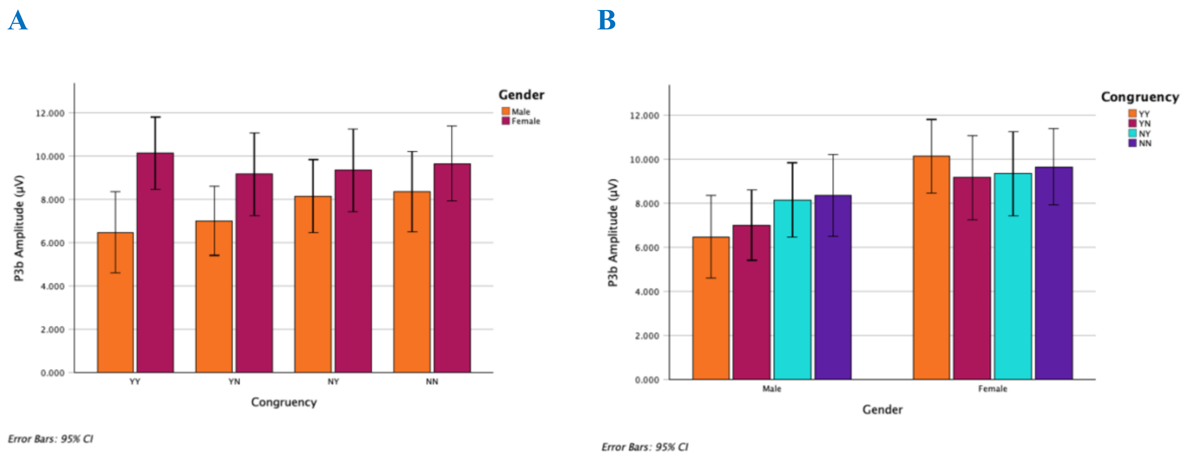


Figure 4.6.6.14 Averaged P3b amplitudes by gender and congruency

Electrode and the P3b There was a significant main effect of the electrodes on P3b amplitude, F (2, 288.001) = 43.707, p < .001. As shown in Figure 4.6.6.14, the P3b amplitudes significantly differed among these three channels.

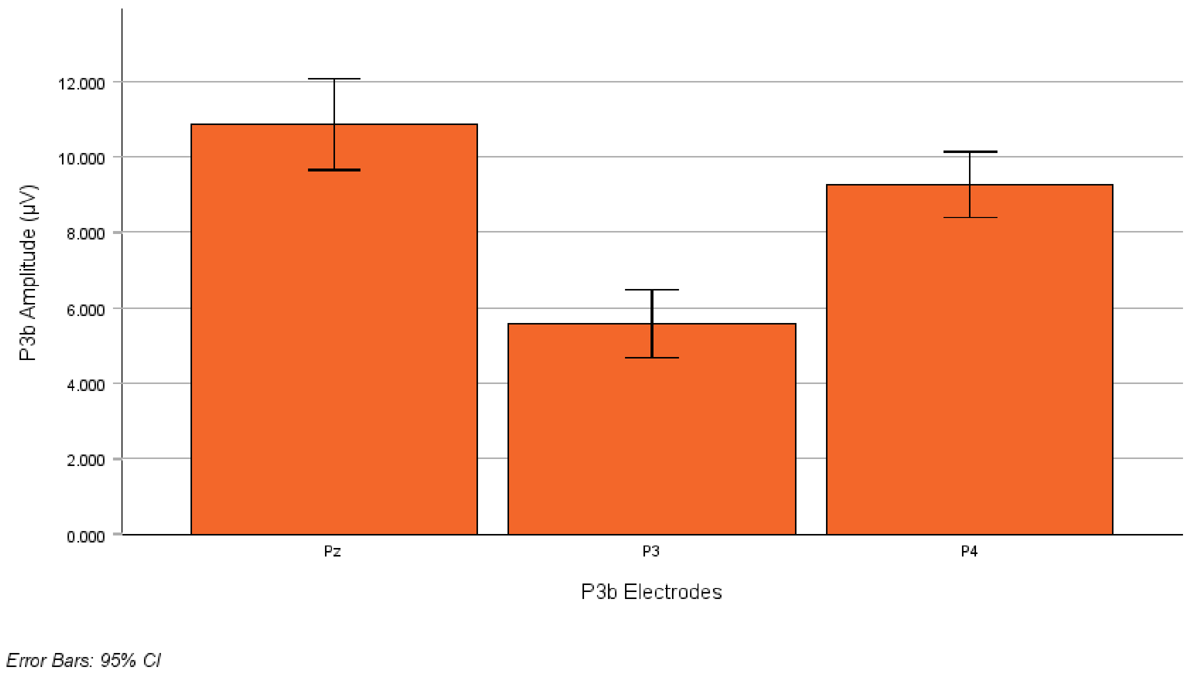


Figure 4.6.6.15 Averaged P3b amplitudes by the electrodes

In summary, the model revealed one statistically significant main effect, the P3b electrodes, and one marginally significant interaction effect between gender and prediction.

4.6.7 Late Positive Potential (LPP)

The LPP is an ERP component that manifests approximately 300 milliseconds following the onset of a stimulus (Hajcak et al., 2010). It is recognised as a neural marker encompassing emotion regulation (Dennis & Hajcak, 2009) or cognitive reappraisal in children participating in cognitive reappraisal tasks (Babkirk et al., 2015; Van Cauwenberge et al., 2017). The literature firmly establishes that the LPP demonstrates sensitivity to the valence of stimuli, being significantly more pronounced for emotional stimuli (e.g., pleasant or unpleasant) than neutral stimuli (DeCicco et al., 2012; Hajcak et al., 2010). Multiple authors have proposed that the LPP acts as an indicator of the dynamic level of arousal provoked by emotional stimuli (Hajcak et al., 2010). However, findings regarding the LPP concerning reappraisal exhibit a degree of variability, as elucidated in Section 2.4. It is important to note that the time window for the LPP in young children is observed to occur later than that noted in studies involving adults (Dennis & Hajcak, 2009). The LPP literature employs various time windows, which range from 300 to 2000 milliseconds post-stimulus onset (e.g., Dennis & Hajcak, 2009). In the SJP literature, the LPP has been recorded at 600 to 1000 milliseconds after feedback onset (Gu et al., 2020). Based on visual inspection and the review of existing literature, the LPPs were calculated by extracting the mean amplitudes from two distinctive post-feedback time windows: 800 – 1000 ms post-feedback and 1000 – 2000 ms post-feedback at P3, Pz and P4.

Prediction Valence and the LPP

The preliminary visual inspection of the grand waveforms (Figure 4.6.7.1) indicated that the LPP amplitude for No Prediction was greater than for Yes Prediction at Pz and P3. The LPP difference between Yes and No Prediction was less pronounced at P4.

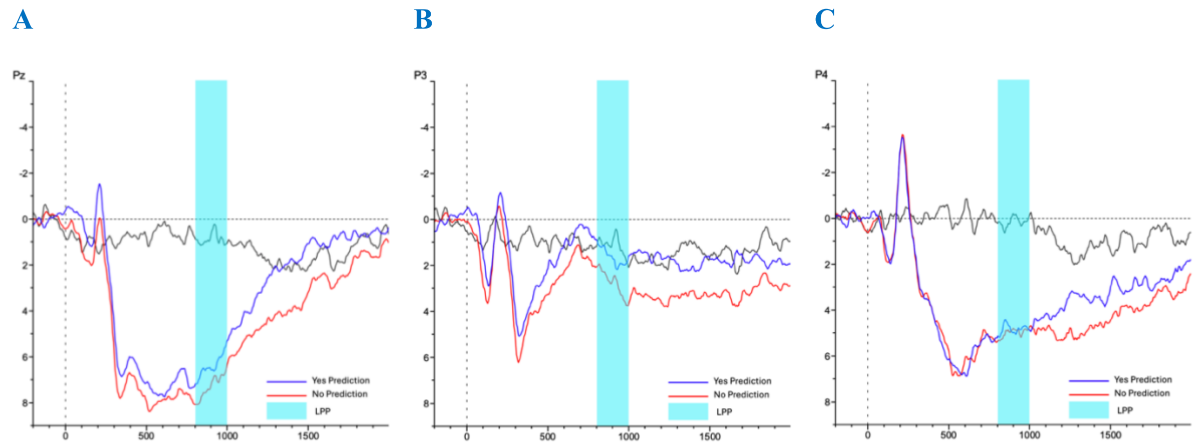


Figure 4.6.7.1 LPP grand averaged waveforms by Prediction Valence

Note: The figures illustrate grand averaged waveforms from two conditions: Yes Prediction (in blue) and No Prediction (in red), extracted separately from the Pz (A), P3 (B), and P4 (C) channels. They display the LPP between 800 ms and 1000 ms, as highlighted, after the onset of feedback stimuli, indicated as 0

Prediction Valence The statistical analysis confirmed the observations mentioned above. There was no main effect of Prediction Valence in the model, F (1, 288) = .001, p = .975. However, when considered separately, the estimated marginal mean indicated that the LPP for No Prediction (M = 7.751, SE = .669) was larger than for Yes Prediction (M = 6.704, SE = .669) (see Figure 4.6.7.2). These means were averaged across Pz, P3, and P4. A pairwise comparison revealed that the overall mean difference between Yes and No Predictions was statistically significant, $|M_{diff}|$ = 1.048, SE = .466, df = 288, p =.025, 95% CI [.130, 1.966].

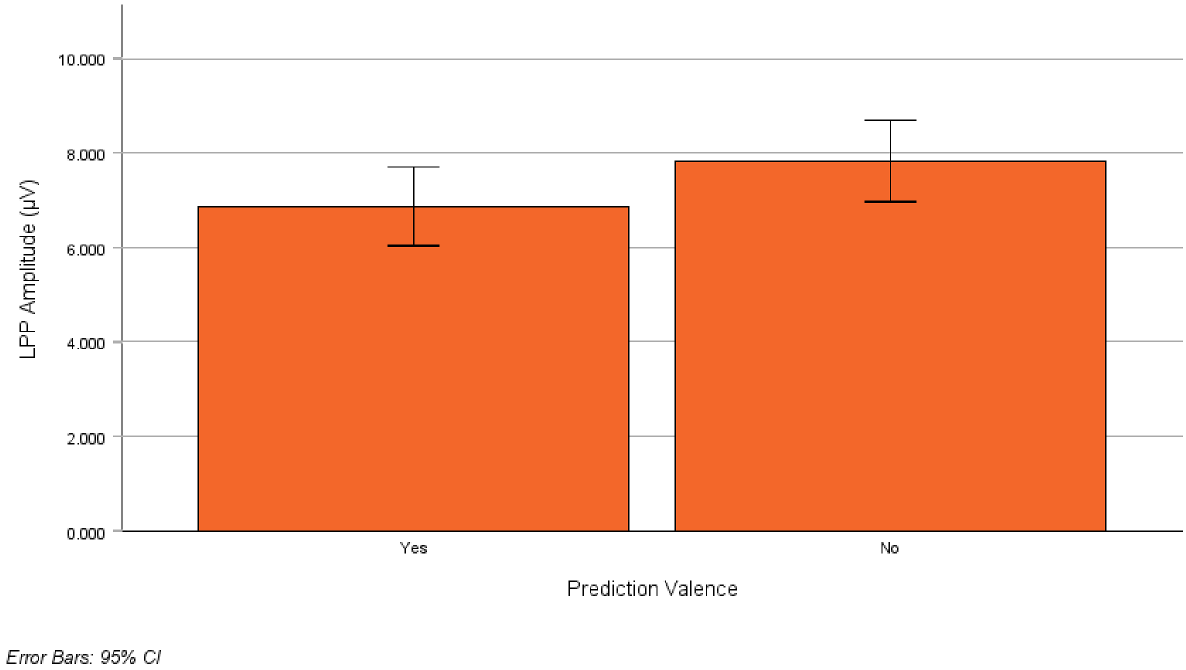


Figure 4.6.7.2 Averaged LPP amplitudes by Prediction Valence

Prediction Valence x *the LPP Electrodes* In general, the interaction effect of Prediction Valence and the LPP Electrodes was insignificant: F (2, 288) = .312, p = .732. As shown in Figure 4.6.7.3A and Table 4.6.7.1, the amplitudes between the selected channels differed within the same valence. However, when evaluated within the same channel (see Figure 4.6.7.3B), the amplitude difference between valences did not show statistical significance.

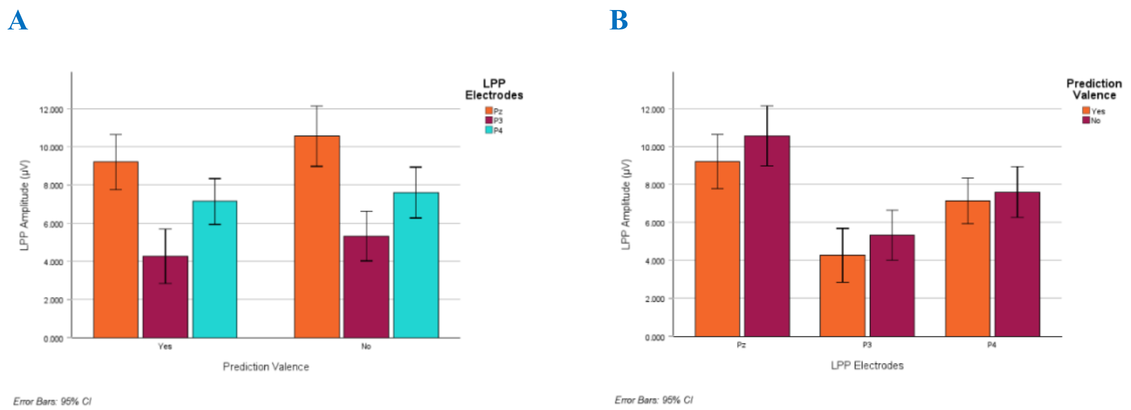


Figure 4.6.7.3 Averaged LPP amplitudes by Prediction Valence and the electrodes

Table 4.6.7.1 Pairwise comparison between the LPP electrodes by Prediction Valence

Prediction Valence	(I) LPP Electrodes	(J) LPP Electrodes	Mean Difference (I-J)	Std. Error	*df*	*Sig.*[c]	95% Confidence Interval for Difference[c] Lower Bound	Upper Bound
Yes	Pz	P3	4.743*	.806	288.000	<.001	2.808	6.678
	Pz	P4	1.914	.806	288.000	.054	-.021	3.849
	P3	P4	-2.829*	.806	288.000	.002	-4.764	-.894
No	Pz	P3	4.954*	.806	288.000	<.001	3.019	6.889
	Pz	P4	2.777*	.806	288.000	.002	.842	4.712
	P3	P4	-2.177*	.806	288.000	.022	-4.112	-.243

Feedback Valence and the LPP

The preliminary visual inspection of the grand waveforms by Feedback Valence (see Figure 4.6.7.4) revealed that the LPP amplitude for No Feedback was greater than for Yes Feedback at Pz. The LPP difference between Yes and No Feedback was not apparent at P3 and P4.

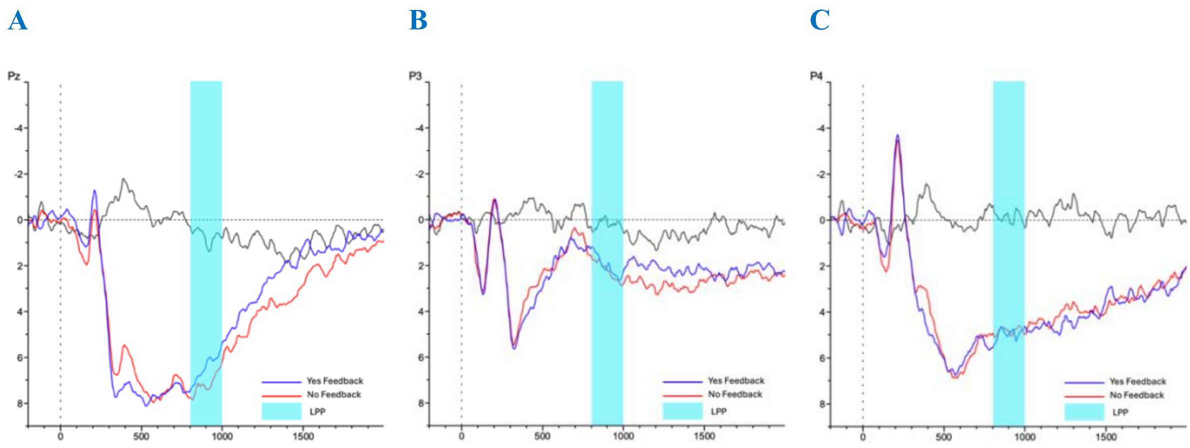


Figure 4.6.7.4 LPP grand averaged waveforms by Feedback Valence

Note: The figures depict grand averaged waveforms from two conditions: Yes Feedback (in blue) and No Feedback (in red), extracted separately from the Pz (A), P3 (B), and P4 (C) channels. They illustrate the LPP between 800 ms and 1000 ms, as highlighted, after the onset of feedback stimuli,

Feedback Valence The model revealed no main effect of Feedback Valence in the model, F (1, 288) = .780, p = .378. As shown in Figure 4.6.7.5, the LPP difference between Yes and No Feedback was not significant.

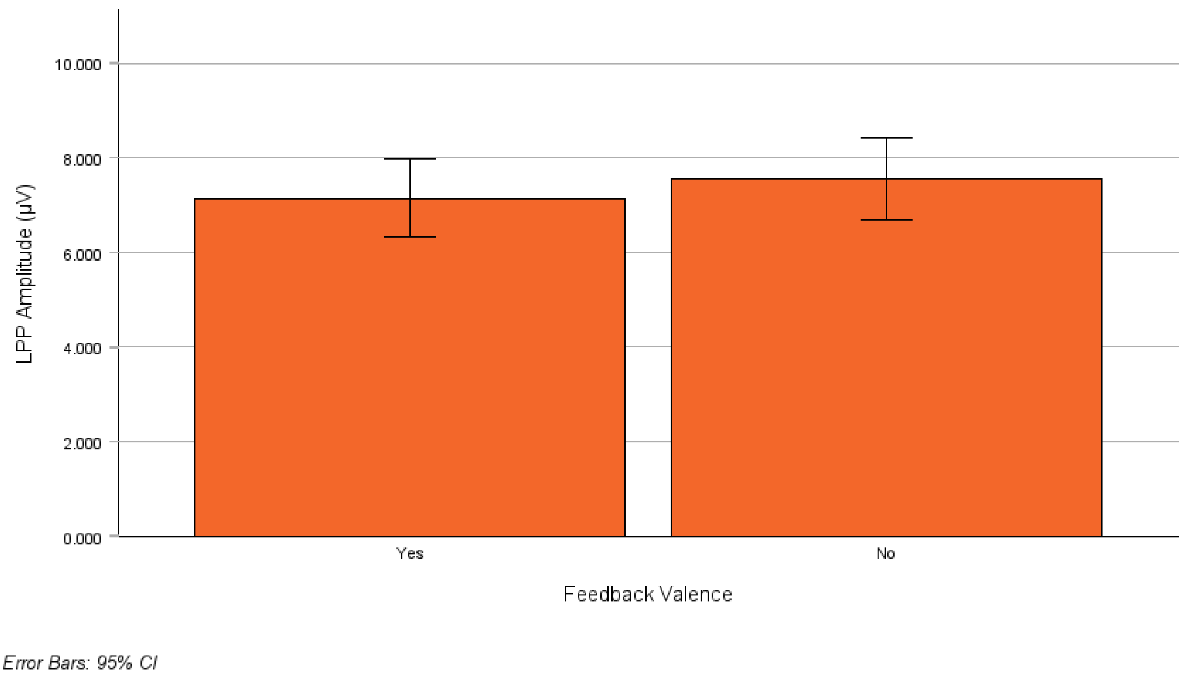


Figure 4.6.7.5 Averaged LPP amplitudes by Feedback Valence

Feedback Valence x *the LPP Electrodes* There was no significant interaction effect between Feedback Valence and the LPP electrodes, F (2, 288) = .357, p = .700. As shown in Figure 4.6.7.6A and Table 4.6.7.2, the amplitudes between the selected channels differed within the same valence. However, within the same channel, the amplitude difference between the two valence conditions did not show statistical significance (See Figure 4.6.7.6B). Figure 4.6.7.7 illustrates the grand average topographical maps of the LPP for Yes Feedback (A) and No Feedback (B).

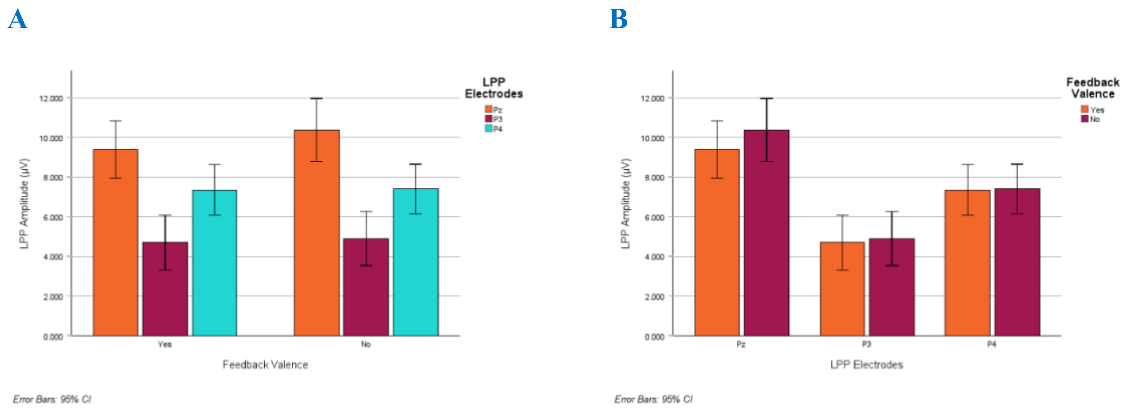


Figure 4.6.7.6 Averaged LPP amplitudes by Feedback Valence and the electrodes

Table 4.6.7.2 Pairwise comparison between the LPP electrodes by Feedback Valence

Feedback Valence	(I) LPP Electrodes	(J) LPP Electrodes	Mean Difference (I-J)	Std. Error	*df*	*Sig.*[c]	95% Confidence Interval for Difference[c]	
							Lower Bound	Upper Bound
Yes	Pz	P3	4.442*	.806	288.000	<.001	2.507	6.377
	Pz	P4	1.919	.806	288.000	.053	-.016	3.854
	P3	P4	-2.523*	.806	288.000	.006	-4.458	-.588
No	Pz	P3	5.255*	.806	288.000	<.001	3.320	7.190
	Pz	P4	2.772*	.806	288.000	.002	.837	4.707
	P3	P4	-2.483*	.806	288.000	.007	-4.418	-.548

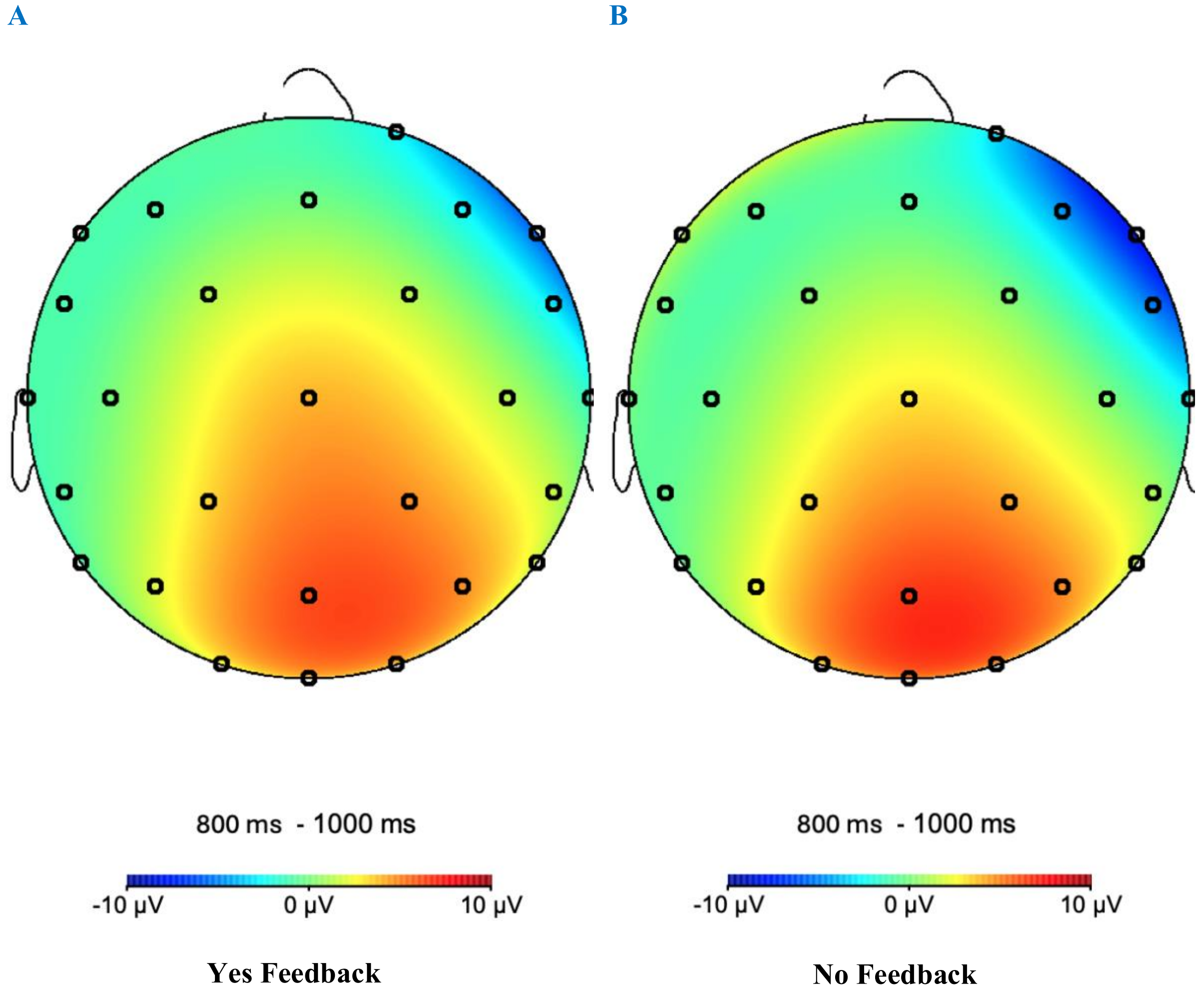


Figure 4.6.7.7 Grand average topographical maps of the LPP

Congruency and the LPP

The preliminary visual inspection of the LPP grand waves by congruency types (Figure 4.6.7.8) indicated that the LPP for the expected rejection (NN) was the largest at Pz. The LPP amplitude for expected acceptance (YY) was the smallest at P3. Based on the visual inspection, the differences in LPP amplitude among the four contingency categories were less apparent at P4.

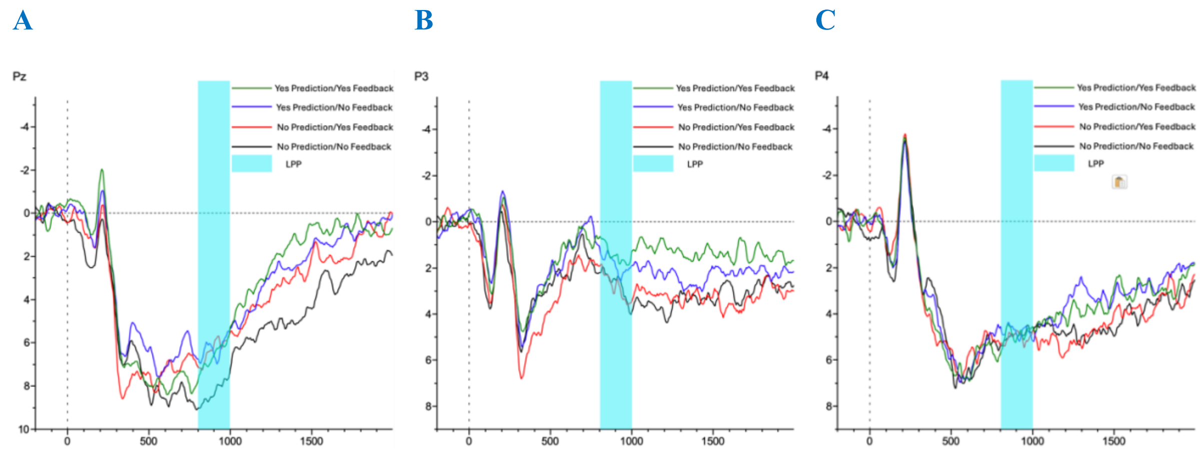


Figure 4.6.7.8 LPP grand averaged waveforms by congruency type

Note: The figures illustrate the grand averaged waveforms from four contingency conditions: YY (in green), YN (in blue), NY (in red), and NN (in black), extracted separately from the Pz (A), P3 (B), and P4 (C) channels. They show the LPP between 800 ms and 1000 ms, as highlighted, after the onset of feedback stimuli, indicated as 0.

Congruency The model showed no significant interaction effect between Prediction Valence and Feedback Valence, $F(1, 288) = .287$, $p = .593$. The pairwise comparison revealed that only the LPP amplitude difference between unexpected rejection (YN) and expected rejection (NN) was statistically significant, $|M_{diff}| = 1.828$, $SE = .660$, $df = 288$, $p = .035$, 95% *CI* [-3.576, -.081] (See Figure 4.6.7.9).

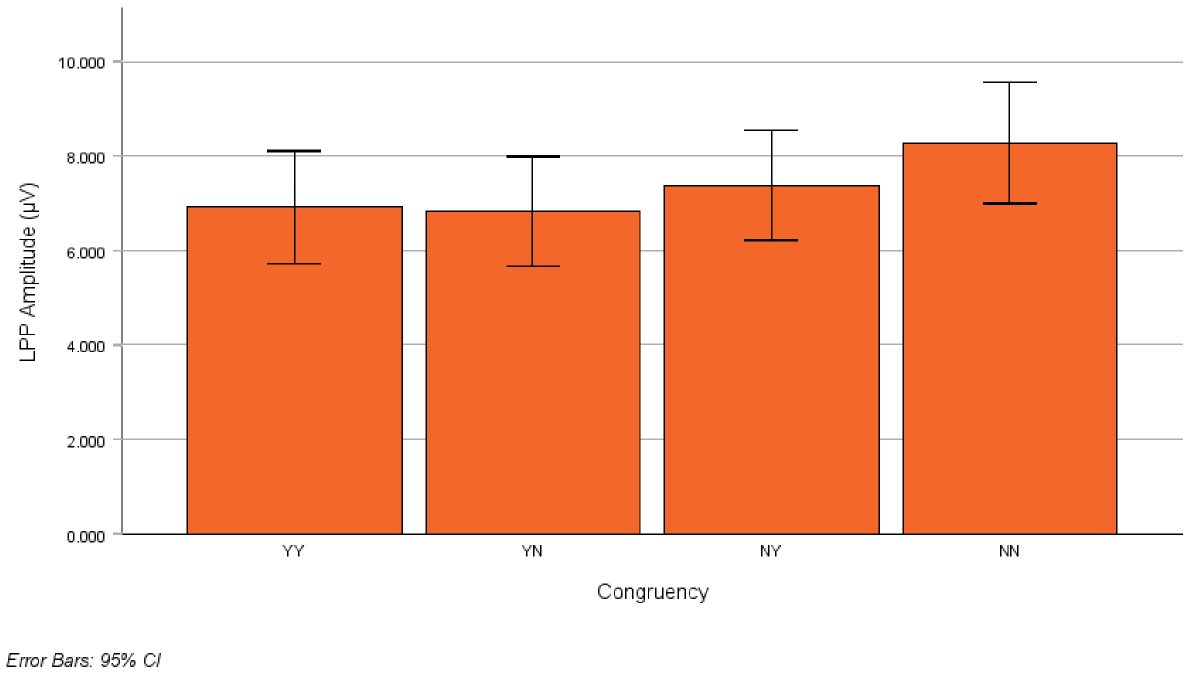


Figure 4.6.7.9 Averaged LPP amplitudes by congruency type

Congruency x *the LPP electrodes* No significant interaction effect between congruency and the LPP electrodes was discovered, F (2, 288) = 1.125, p = .326. When controlling for the electrodes, the pairwise comparison revealed that the LPP amplitude difference between unexpected rejection (YN) and expected rejection (NN) remained statistically significant, but only at Pz, $|M_{diff}|$ = 3.160, SE = 1.140, df = 288, p = .035, 95% CI [-6.182, -.139]. No other differences among the four congruency types were significant at Pz, P3, and P4 (see Figure 4.6.7.10A). Figure 4.6.7.10B illustrates the LPP among the four congruency types within each channel. As indicated in Table 4.6.7.3, the LPP differences between Pz and P3 for all four congruency types were statistically significant. The LPP difference between Pz and P4 was statistically significant only for expected rejection (NN). The LPP difference between P3 and P4 was statistically significant solely for unexpected rejection (YN). Additionally, a marginally significant difference was observed between P3 and P4 for expected acceptance (YY).

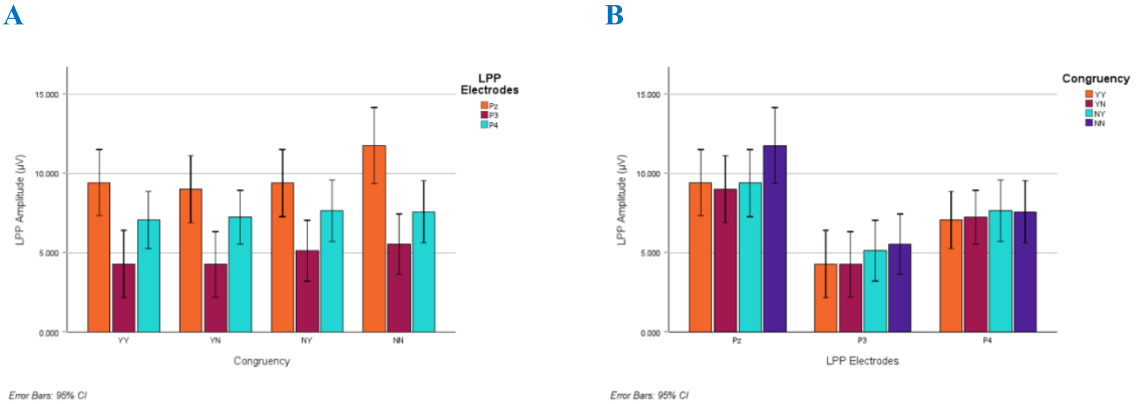


Figure 4.6.7.10 Averaged LPP amplitudes by congruency type and the electrodes

Table 4.6.7.3 Pairwise comparison between the congruency types by the LPP electrodes

Congruency	(I) LPP Electrodes	(J) LPP Electrodes	Mean Difference (I-J)	Std. Error	*df*	*Sig.*[c]	95% Confidence Interval for Difference[c]	
							Lower Bound	Upper Bound
YY	Pz	P3	4.999*	1.139	288.000	<.001	2.263	7.736
	Pz	P4	2.286	1.139	288.000	.131	-.450	5.022
	P3	P4	-2.713	1.139	288.000	.053	-5.450	.023
YN	Pz	P3	4.486*	1.139	288.000	<.001	1.750	7.223
	Pz	P4	1.542	1.139	288.000	.443	-1.195	4.278
	P3	P4	-2.945*	1.139	288.000	.030	-5.681	-.208
NY	Pz	P3	3.885*	1.139	288.000	.002	1.149	6.622
	Pz	P4	1.552	1.139	288.000	.437	-1.184	4.288
	P3	P4	-2.334	1.139	288.000	.119	-5.070	.403
NN	Pz	P3	6.023*	1.139	288.000	<.001	3.287	8.760
	Pz	P4	4.002*	1.139	288.000	.002	1.266	6.738
	P3	P4	-2.021	1.139	288.000	.214	-4.758	.715

Gender and the LPP

Gender No main effect of gender was found, F (1, 24.001) = 2.351, p = .138. As shown in Figure 4.6.7.11, the gender difference was not significant.

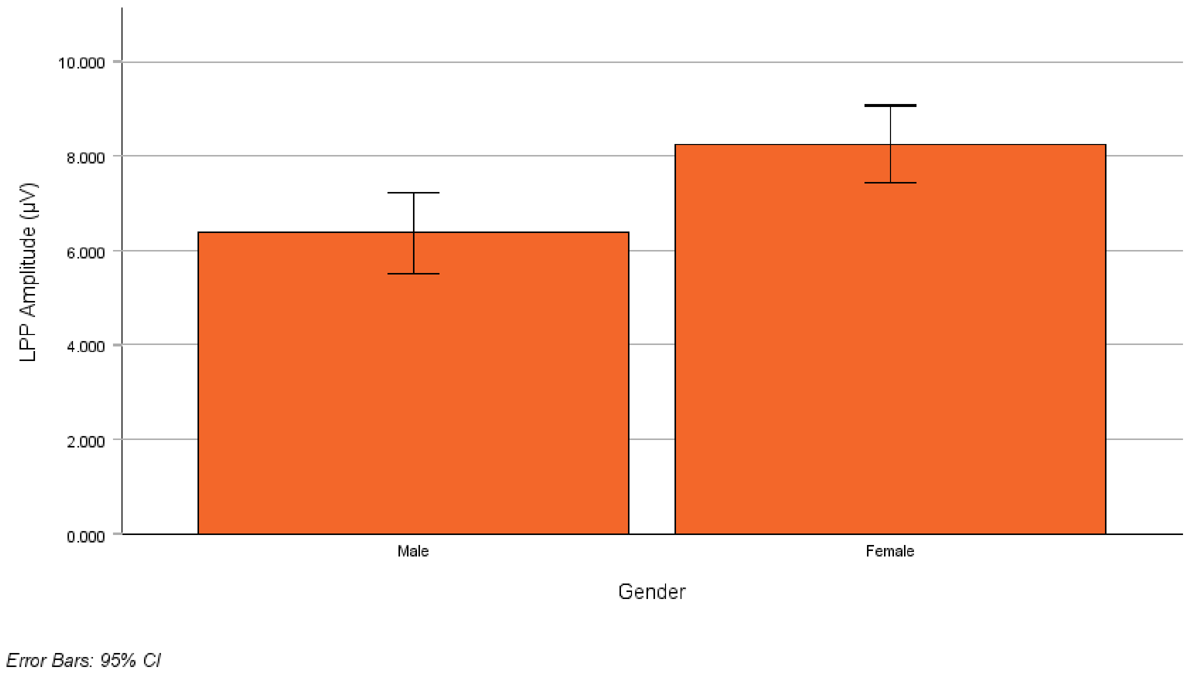


Figure 4.6.7.11 Averaged LPP amplitudes by gender

Gender x *Prediction Valence* There was no significant interaction effect of Gender and Prediction Valence, F (1, 288) = 2.458, p = .118. However, the model's estimated marginal mean indicated a marginally significant gender difference for Yes Prediction. When the prediction was positive, the LPP for girls (M = 8.080, SE = .927) was greater than that for boys (M = 5.327, SE = .999). The pairwise comparison showed this difference to be marginally significant, $|M_{diff}|$ = 2.754, SE = 1.388, df = 31.056, p = .056, 95% CI [-.077, 5.584]. The LPP gender difference between girls and boys for No Predictions was not significant, $|M_{diff}|$ = 1.236, SE = 1.388, df = 31.056, p = .380, 95% CI [-1.595, 4.067]. Figure 4.6.7.12A illustrates these gender differences while comparing the Yes and No Predictions. As shown in Figure 4.6.7.12B, there was a statistically significant LPP difference between Yes (M = 5.327, SE = .999) and No (M = 7.133, SE = .999) predictions only for the boys, $|M_{diff}|$ = 1.806, SE = .697, df = 288, p = .010, 95% CI [-3.178, -.435].

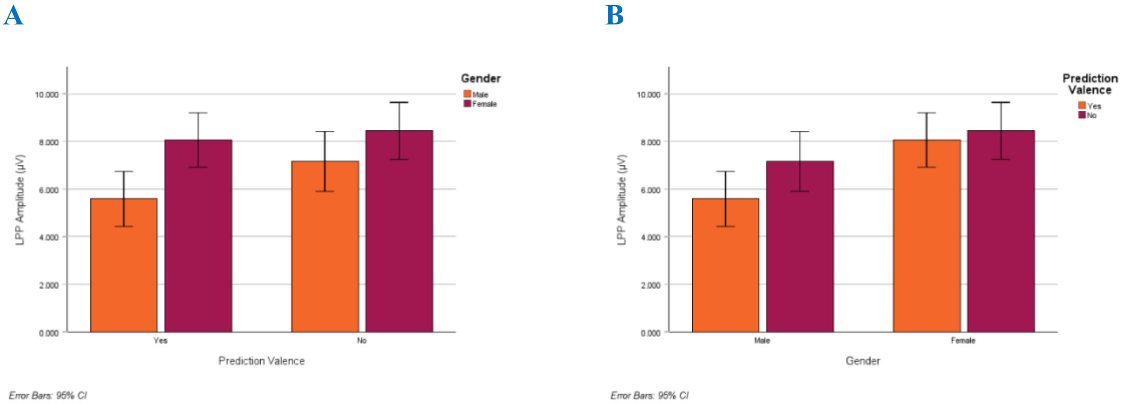


Figure 4.6.7.12 Averaged LPP amplitudes by gender and Prediction Valence

Gender x *Feedback Valence* There was a significant interaction effect of Gender and Feedback Valence on the LPP, F (1, 288) = 4.528, p = .034. The estimated marginal means indicated that the LPP amplitude for girls (M = 8.602, SE = .927) was greater than that for boys (M = 5.577, SE = .999) when the Feedback Valence was positive. The pairwise comparison showed that this gender difference for Yes Feedback was statistically significant, $|M_{diff}|$ = 3.025, SE = 1.388, df = 31.056, p = .037, 95% CI [.194, 5.856]. The LPP gender difference between girls and boys for No Feedback was not significant (see Figure 4.6.7.13A). Figure 4.6.7.13B compares the Yes and No Feedback within each gender. There was a marginally significant LPP difference between Yes (M = 5.577, SE = .999) and No Feedback (M = 6.883, SE = .999) for boys, $|M_{diff}|$ = 1.306, SE = .697, df = 288, p = .062, 95% CI [-2.677, .066]. There was no significant LPP difference between Yes and No Feedback for girls.

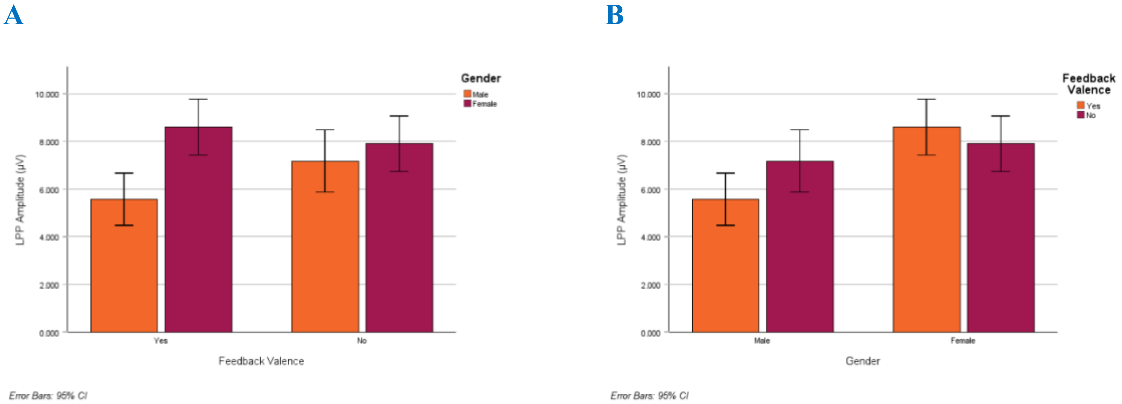


Figure 4.6.7.13 Averaged LPP amplitudes by gender and Feedback Valence

Gender x *Congruency* The statistical analysis did not reveal an interaction effect between congruency and gender, F (1, 288) = .049, p = .824. However, the model's estimated marginal means indicated a statistically significant difference in gender concerning expected acceptance (YY), $|M_{diff}|$ = 3.891, SE = 1.548, df = 47.391, p = .015, 95% CI [.778, 7.004]. Specifically, for expected acceptance (YY), the LPP for girls (M = 8.902, SE = 1.034) was statistically higher than that for boys (M = 5.011, SE = 1.114). No significant gender differences were observed in the other three congruency categories (see Figure 4.6.7.14A). When analysing the LPP across the four congruency types within each gender (Figure 4.6.7.14B), a single significant difference was identified for boys between expected acceptance (YY) (M = 5.011, SE = 1.114) and expected rejection (NN) (M = 8.123, SE = 1.114), $|M_{diff}|$ = 3.112, SE = .985, df = 288, p = .010, 95% CI [-5.722, -.502]. No significant differences were noted among the various congruency types for girls.

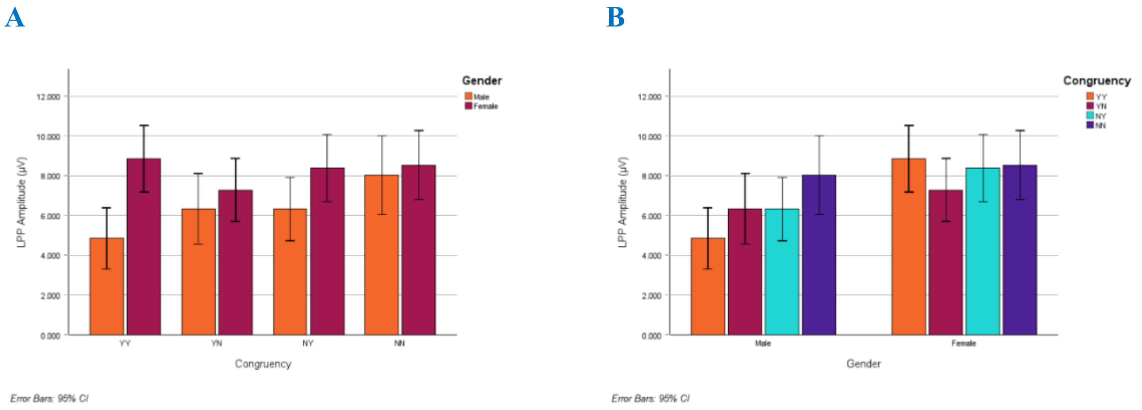


Figure 4.6.7.14 Averaged LPP amplitudes by gender and congruency type

Electrode and the LPP

Electrodes There was a significant main effect of the electrodes on the LPP, $F(2, 288) = 36.233$, $p < .001$. All differences among these three electrodes were statistically significant (see Figure 4.6.7.15).

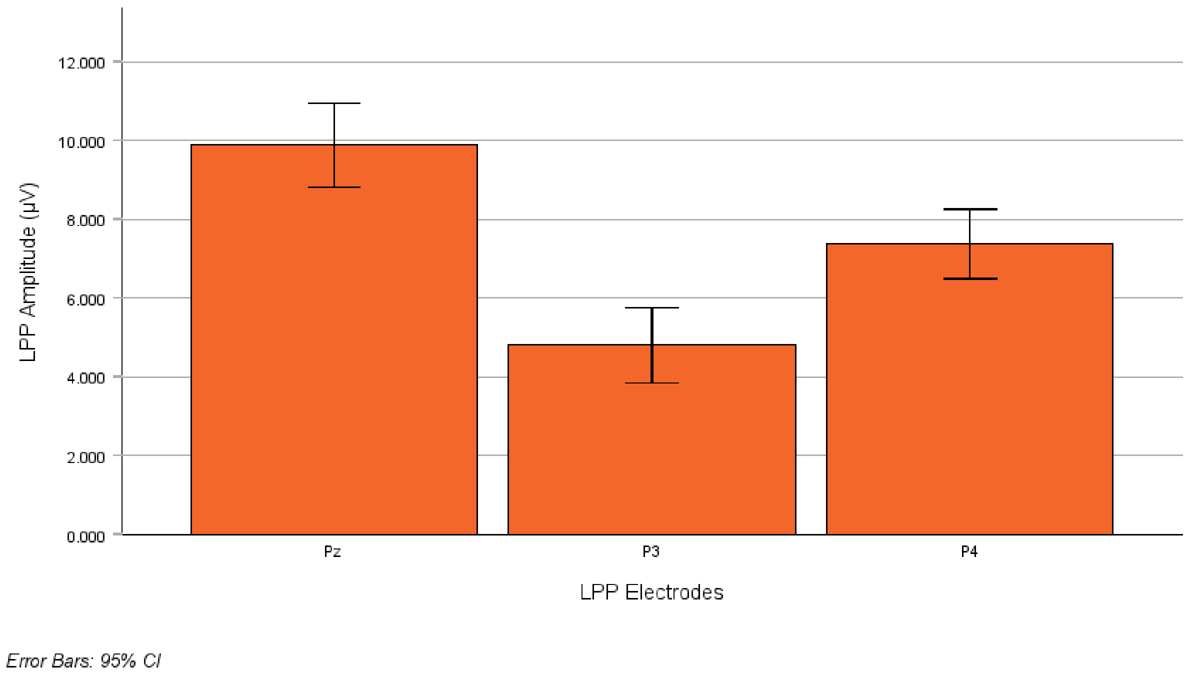


Figure 4.6.7.15 Averaged LPP amplitudes by the electrodes

In summary, the model revealed one significant main effect, the LPP electrodes, and one interaction effect, gender x feedback.

4.6.8 Late Late Positive Potential (LLPP)

Prediction Valence and the LLPP

The preliminary visual inspection indicated that the LLPP for No Prediction was larger than for Yes Prediction at all three sites.

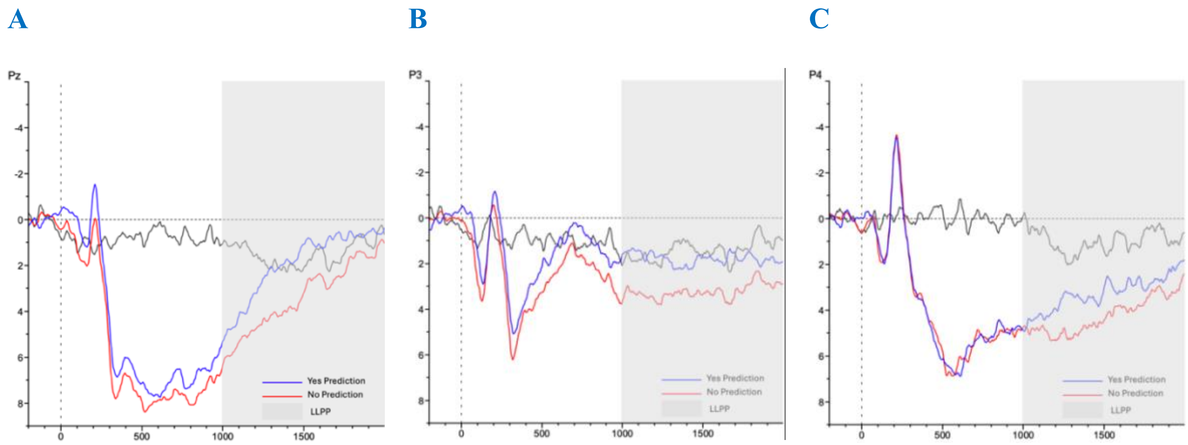


Figure 4.6.8.1 LLPP grand averaged waveforms by Prediction Valence

Note: The figures illustrate grand averaged waveforms from two conditions: Yes Prediction (in blue) and No Prediction (in red), extracted separately from the Pz (A), P3 (B), and P4 (C) channels. They depict the LLPP between 1000 ms and 2000 ms, as highlighted, after the onset of feedback stimuli, indicated as 0.

Feedback Valence and the LPP

Prediction Valence The model showed no main effect of Prediction Valence on the LLPP, F (1, 288) = .753, p = .386. However, the estimated marginal means of the LLPP amplitude averaged across Pz, P3, and P4 indicated that the LLPP for No Prediction (M = 8.949, SE = .644) was larger than for Yes Prediction (M = 7.731, SE = .644) (see Figure 4.6.8.2). The pairwise comparisons revealed that the difference in LLPP amplitude between Yes and No Prediction was statistically significant, $|M_{diff}|$ = 1.218, *SE* = .426, *df* = 288, *p* = .005, 95% *CI* [-2.057, -.379].

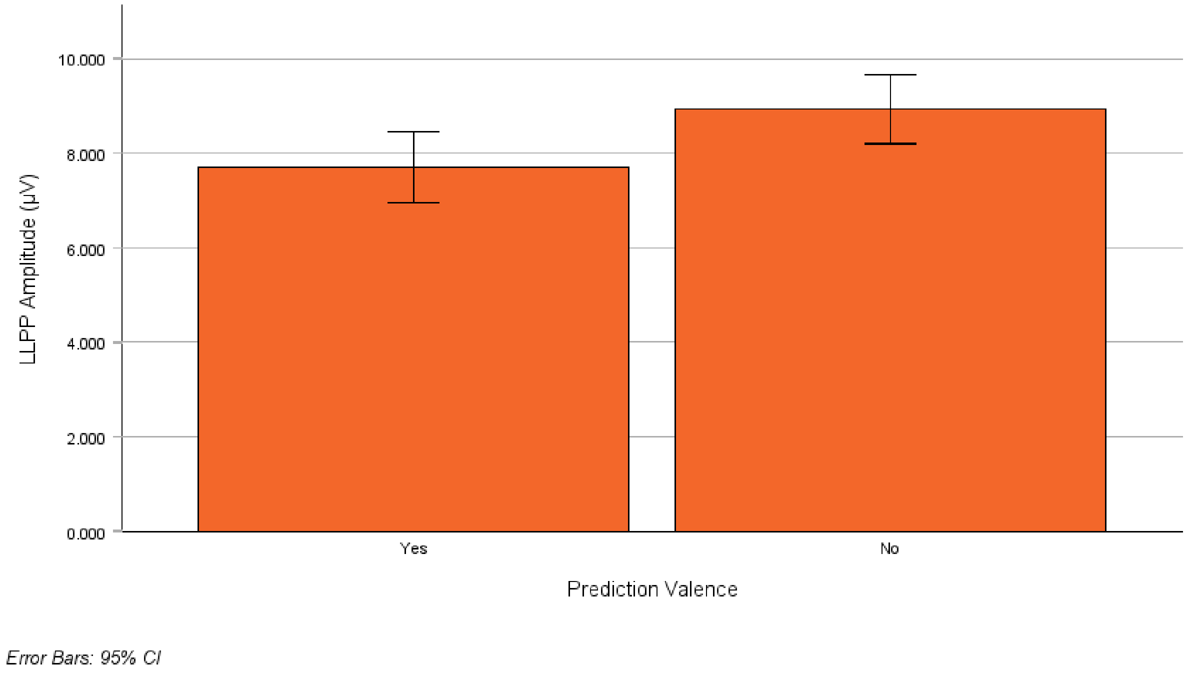


Figure 4.6.8.2 Averaged LLPP amplitudes by Prediction Valence

Prediction Valence x *the LLPP electrode* The Prediction Valence and the LLPP electrodes revealed no significant interaction effect (see Figure 4.6.8.3), *F* (2, 288) = .082, *p* = .921. As shown in Figure 4.6.8.3A, the LLPP amplitudes for No Prediction were larger than for Yes Prediction at Pz, P3, and P4. However, the difference was only marginally significant at P3, $|M_{diff}|$ = 1.450, *SE* = .737, *df* = 288, *p* = .050, 95% *CI* [-2.900, .001], and was not significant for Pz and P4. The comparison of channels within each valence (Figure 4.6.8.3B) did not show statistical significance.

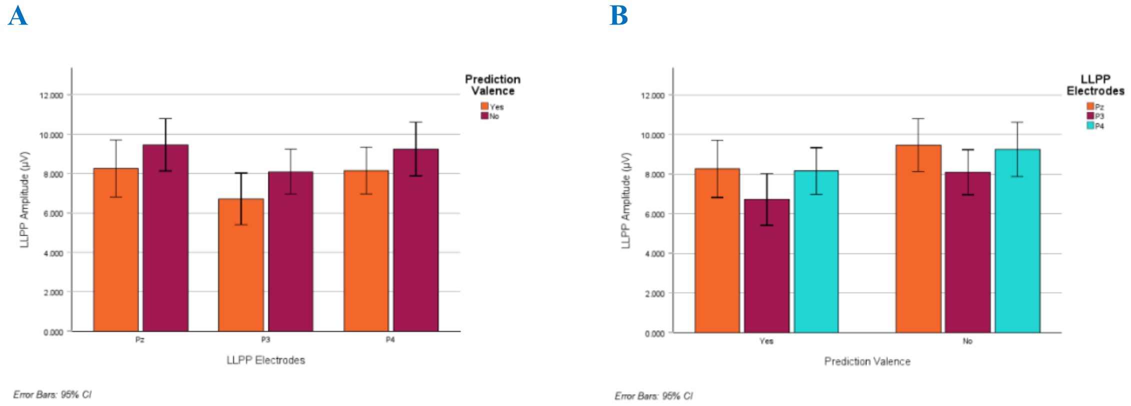


Figure 4.6.8.3 Averaged LLPP amplitudes by Prediction Valence and the electrodes

Feedback Valence and the LLPP

The preliminary visual inspection of the LLPP grand waveforms by Feedback Valence (Figure 4.6.8.4) indicated that the LLPP amplitudes for No Feedback were greater than those for Yes Feedback at Pz and P3. However, the LLPP difference between Yes and No Feedback was less pronounced at P4.

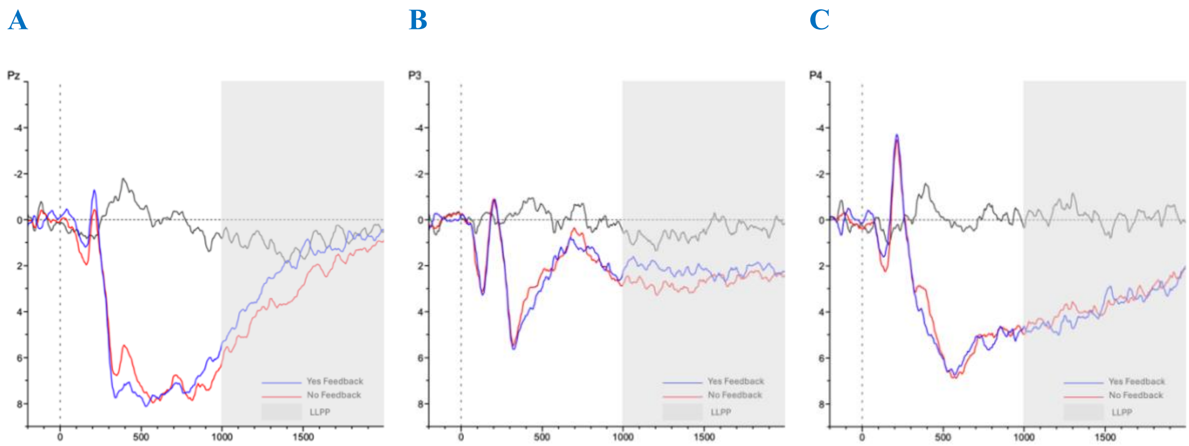


Figure 4.6.8.4 LLPP grand averaged waveforms by Feedback Valence

Note: The figures depict grand averaged waveforms from two conditions: Yes Feedback (in blue) and No Feedback (in red), extracted separately from the Pz (A), P3 (B), and P4 (C) channels. They illustrate the LLPP between 1000 ms and 2000 ms, as highlighted, after the onset of feedback stimuli, indicated as 0.

Feedback Valence The statistical analysis indicated no significant main effect of the Feedback Valence, F (1, 288) = 1.654, p = .199. The pairwise comparisons also showed no significant differences in LLPP amplitude between Yes Feedback (M = 8.050, SE = .644) and No Feedback (M = 8.629, SE = .644) when averaged across Pz, P3, and P4, $|M_{diff}|$ = .579, SE = .426, df = 288, p = .175, 95% CI [-1.418, .260] (Figure 4.6.8.5).

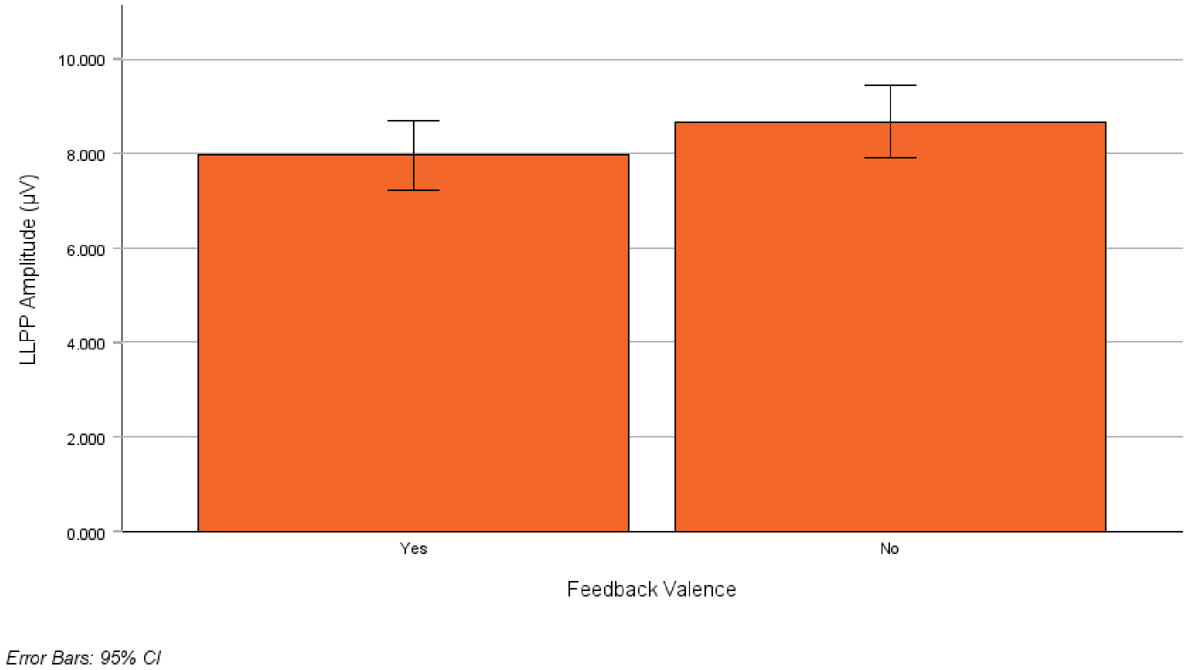


Figure 4.6.8.5 Averaged LLPP amplitudes by Feedback Valence

Feedback Valence x *the LLPP electrodes* Feedback Valence and the LLPP electrodes did not show a significant interaction effect, F (2, 288) = .303, p = .738. None of the differences in Figure 4.6.8.6 were statistically significant. Figure 4.6.8.7 displays the grand average topographical maps of the LLPP by Feedback Valence.

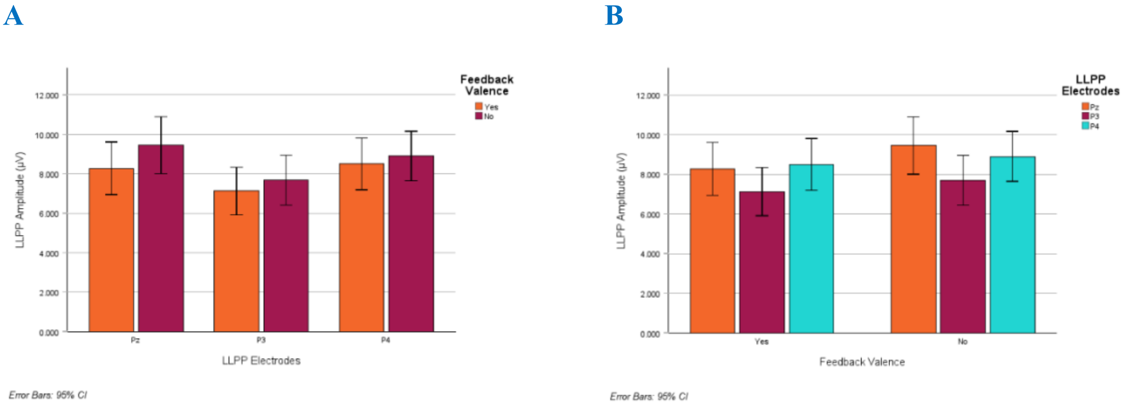


Figure 4.6.8.6 Averaged LLPP amplitudes by Feedback Valence and the electrodes

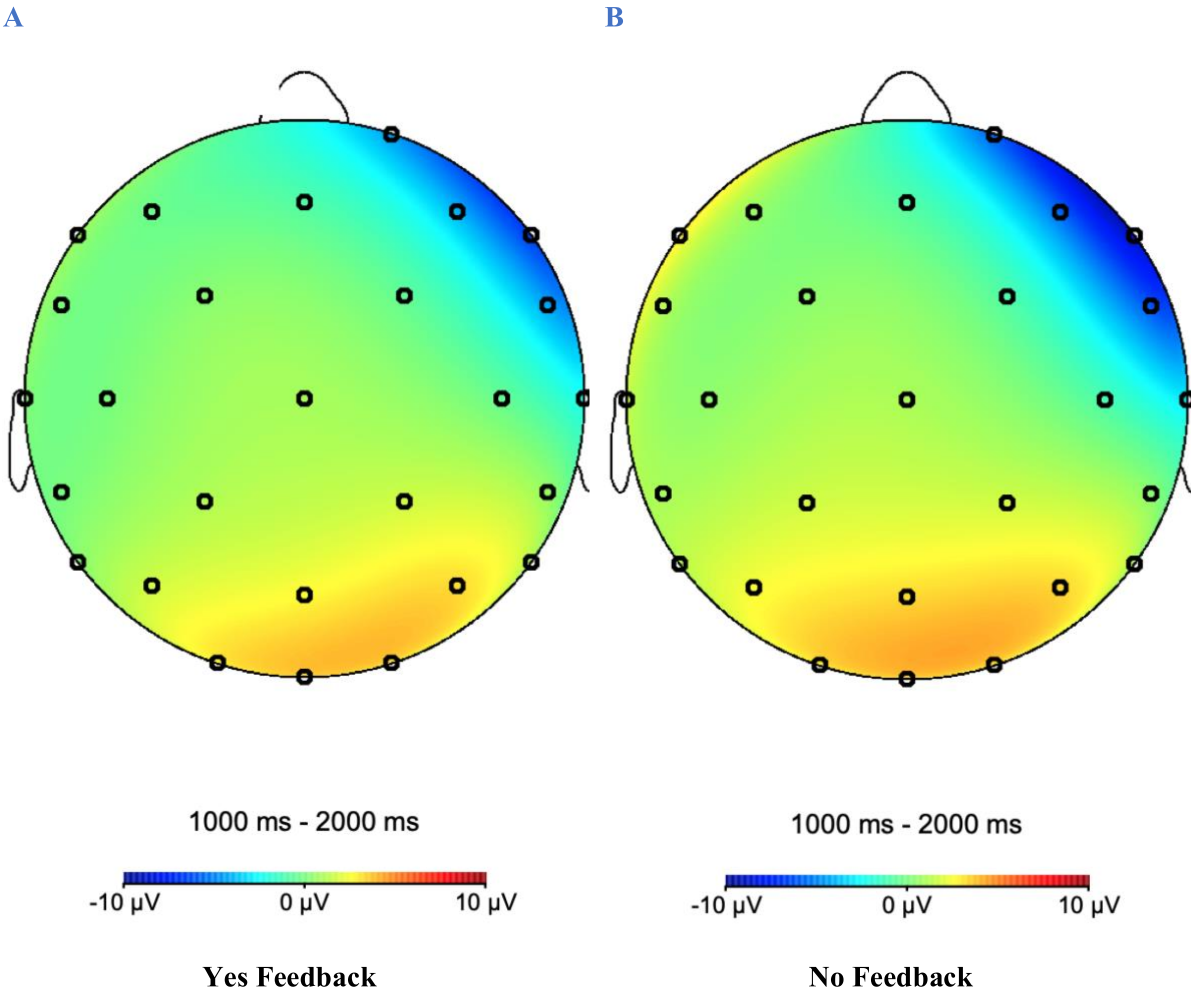


Figure 4.6.8.7 Grand average topographical maps of the LLPP

Congruency and the LLPP

Based on the preliminary visual inspection of the LLPP grand waves by congruency type (Figure 4.6.8.8), the LLPP for expected rejection (NN) was the largest at Pz, followed by the LLPP for unexpected acceptance (NY), while the LLPP for expected acceptance (YY) was the smallest at this site. Additionally, the LLPP at P3 for expected acceptance (YY) was also the smallest. At P4, the LLPP amplitudes for expected acceptance (YY) and unexpected rejection (YN) were greater than those for unexpected acceptance (NY) and expected rejection (NN).

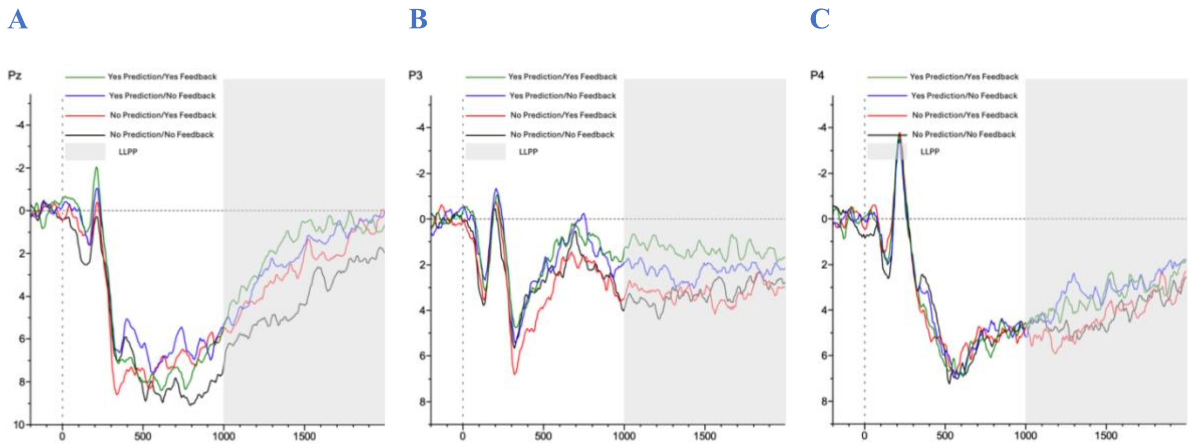


Figure 4.6.8.8 LLPP grand averaged waveforms by congruency type

Note: The figures depict the grand averaged waveforms from four contingency conditions: YY (in green), YN (in blue), NY (in red), and NN (in black), extracted separately from the Pz (A), P3 (B), and P4 (C) channels. They illustrate the LLPP occurring between 1000 ms and 2000 ms, as highlighted, after the onset of feedback stimuli, indicated as 0.

Congruency The statistical analysis revealed a significant effect of congruency, F (1, 288) = 6.105, p = .014. As illustrated in Figure 4.6.8.9, the LLPP amplitude for expected rejection (NN) (M = 9.272, SE = .771) was the highest, followed by the unexpected acceptance (NY) (M = 8.626, SE = .771). The unexpected rejection (YN) was the second lowest (M = 7.987, SE = .771), and the expected acceptance (YY) (M = 7.474, SE = .771) was the lowest. Pairwise comparisons indicated that only the difference in LLPP amplitude between expected acceptance (YY) and expected rejection (NN) was statistically significant, $|M_{diff}|$ = 1.797, SE

= .603, *df* = 288, *p* = .019, 95% *CI* [-3.395, -.200]. No other significant differences were identified among the four congruency categories (see Figure 4.6.8.9).

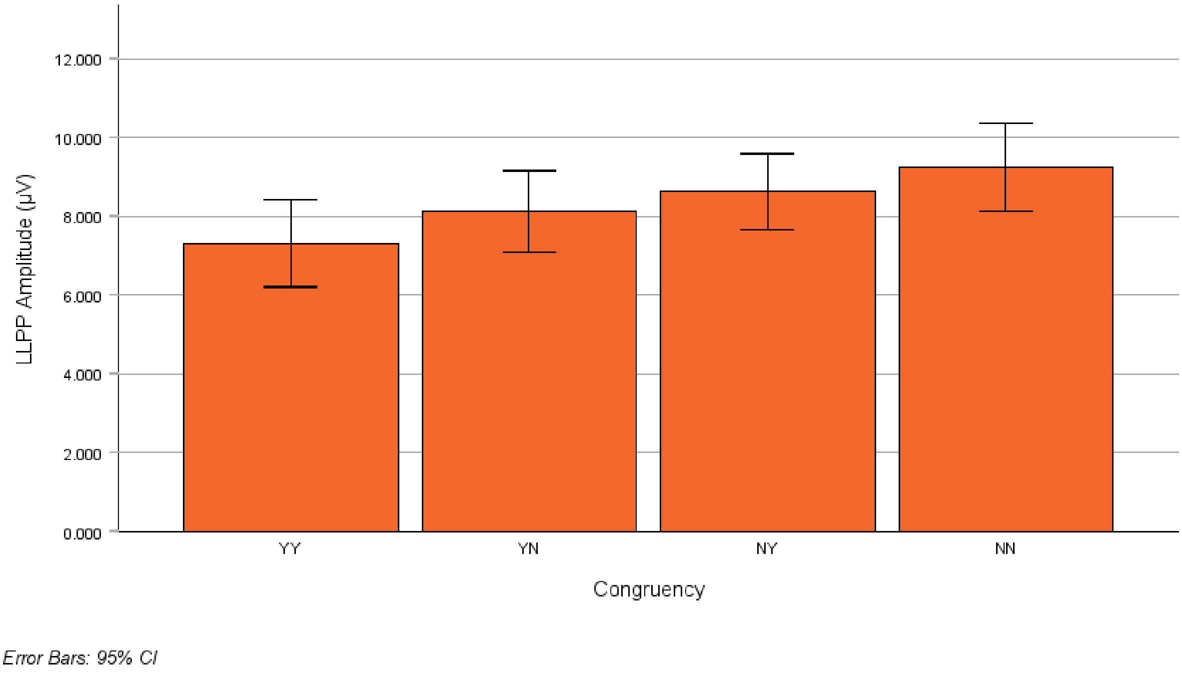


Figure 4.6.8.9 Averaged LLPP amplitudes by congruency type

Congruency x *the LLPP Electrodes* No significant interaction effect was found between congruency and the LLPP electrodes (see Figure 4.6.8.10), F (2, 288) = .735, p = .480. None of the differences presented in Figure 4.6.8.10 were statistically significant.

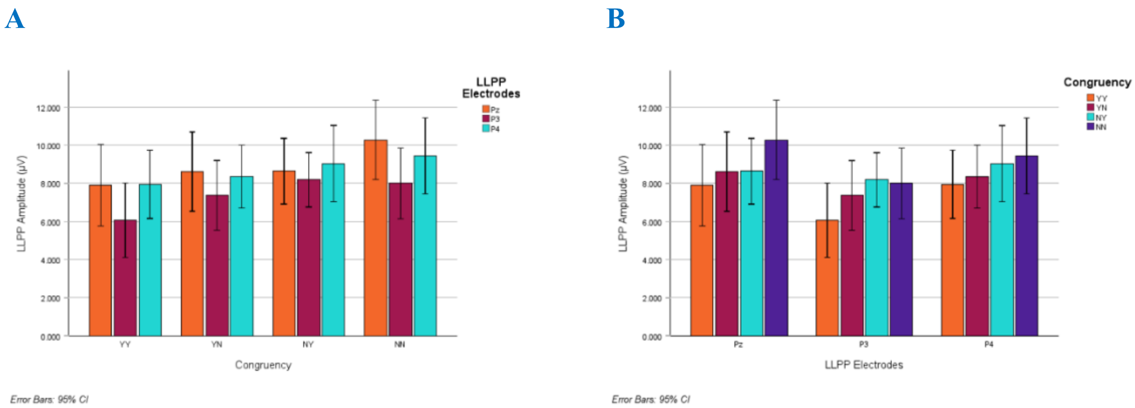


Figure 4.6.8.10 Averaged LLPP amplitudes by congruency type and the electrodes

Gender and the LLPP

Gender There was no significant effect of gender on the LLPP, F (1, 24) = .164, p = .689. Additionally, no significant gender difference was found in the pairwise comparison (see Figure 4.6.8.11).

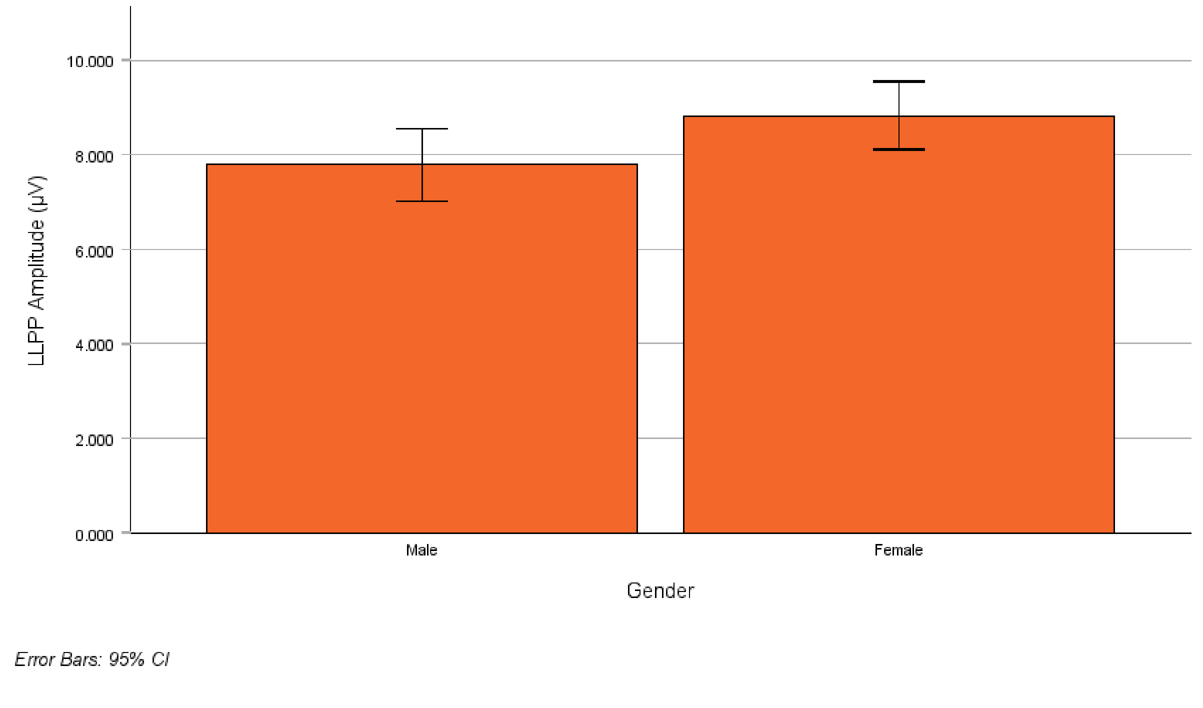


Figure 4.6.8.11 Averaged LLPP amplitudes by gender

Gender x *Prediction Valence* The interaction effect of Gender x Prediction Valence was not significant, F (1, 288) = .104, p = .747. As shown in Figure 4.6.8.12(A), the LLPP for No Prediction was higher than the LLPP for Yes Prediction for both genders. However, the LLPP amplitude differences between Yes Prediction (M = 7.404, SE = .962) and No Prediction (M = 8.765, SE = .962) for boys were statistically significant, $|M_{diff}|$ = 1.361, SE = .637, df = 288, p = .033, 95% CI [-2.615, -.108]. In contrast, the LLPP amplitude differences between Yes Prediction (M = 8.057, SE = .893) and No Prediction (M = 9.133, SE = .893) for girls were not significant, $|M_{diff}|$ = 1.076, SE = .591, df = 288, p = .070, 95% CI [-2.239, .088]. None of the comparisons displayed in 4.6.8.12(B) were statistically significant.

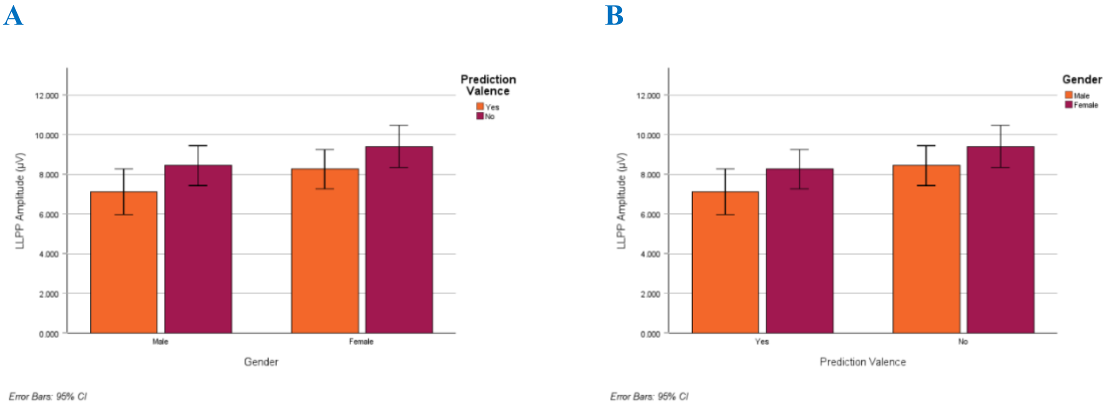


Figure 4.6.8.12 Averaged LLPP amplitudes by gender and Prediction Valence

Gender x *Feedback Valence* The interaction effect of gender and feedback valence was statistically significant in the model, F (1, 288) = 11.367, $p < .001$. As shown in Figure 4.6.8.13(A), for boys, the LLPP amplitude for Yes Feedback (M = 7.049, SE = .962) was significantly smaller than that for No Feedback (M = 9.120, SE = .962). No other significant differences were found in Figure 4.6.8.13.

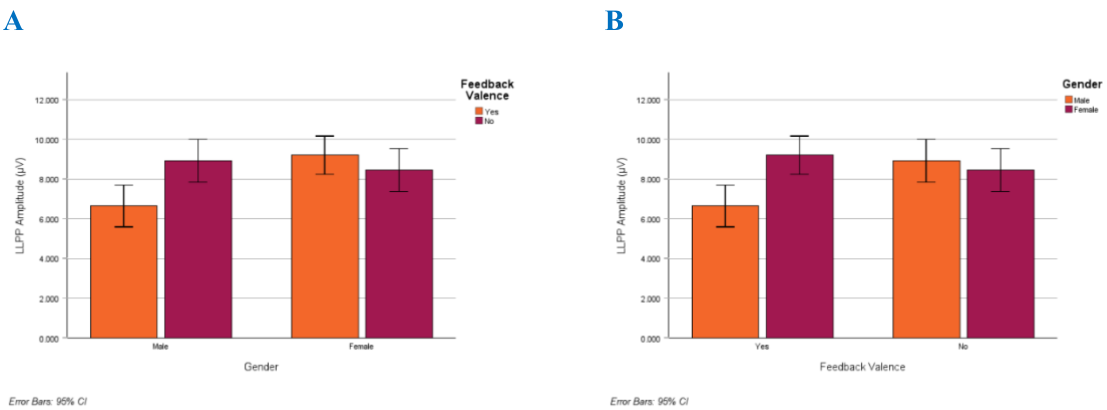


Figure 4.6.8.13 Averaged LLPP amplitudes by gender and Feedback Valence

Gender x *Congruency* There was no significant interaction effect between gender and congruency, F (1, 288) = .633, p = .427. As displayed in Figure 4.6.8.14A, for the boys, the LLPP amplitude difference between expected ejection (NN) and expected acceptance (YY) was statistically significant, $|M_{diff}|$ = 3.432, SE = .900, df = 288.009, p = .001, 95% CI [1.046, 5.817]. Additionally, the LLPP amplitude difference between expected acceptance (YY) and unexpected rejection (YN) was marginally significant, $|M_{diff}|$ = 2.356, SE = .900, df = 288.009, p = .055, 95% CI [-4.742, .029]. No other significant differences among the congruency types were identified for the boys. For the girls, there were no statistically significant differences among the congruency types. None of the gender differences shown in Figure 4.6.8.14B was statistically significant.

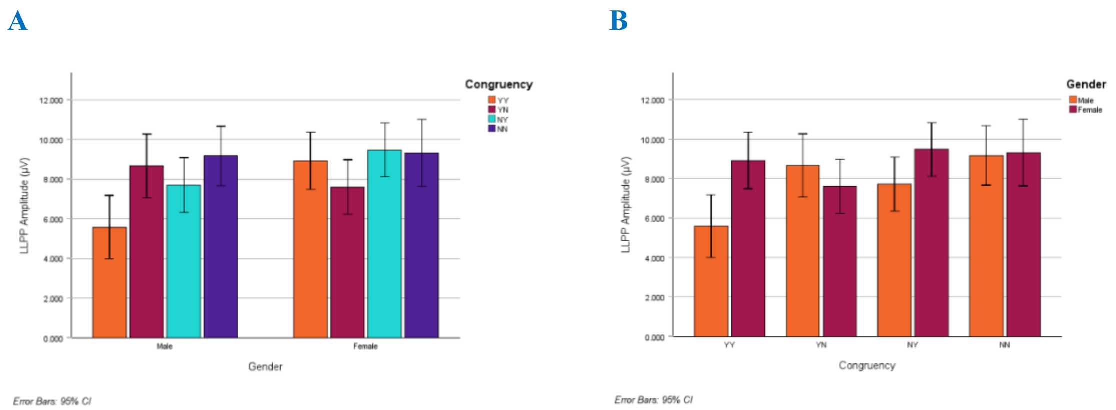


Figure 4.6.8.14 Averaged LLPP amplitudes by congruency type

Electrode and the LLPP

Electrode The electrodes had a significant effect on the LLPP, F (2,288) = 4.552, p = .011. The estimated marginal mean indicated that the LLPP at Pz (M = 8.845, SE = .678) was the highest, closely followed by the LLPP at P4 (M = 8.740, SE = .678). The LLPP at P3 (M = 7.435, SE = .678) was the lowest among these channels. A pairwise comparison showed that the mean LLPP amplitude difference between Pz and P3 was statistically significant, $|M_{diff}|$ = 1.410, SE

= .521, *df* = 288, *p* = .021, 95% *CI* [.160, 2.661]. The mean LLPP amplitude difference between P4 and P3 was also statistically significant, |M*diff*| = 1.305, *SE* = .521, *df* = 288, *p* = .038, 95% *CI* [.054, 2.555]. There was no significant LLPP difference between Pz and P4. The mean LLPP amplitudes for each channel are illustrated in Figure 4.6.8.15.

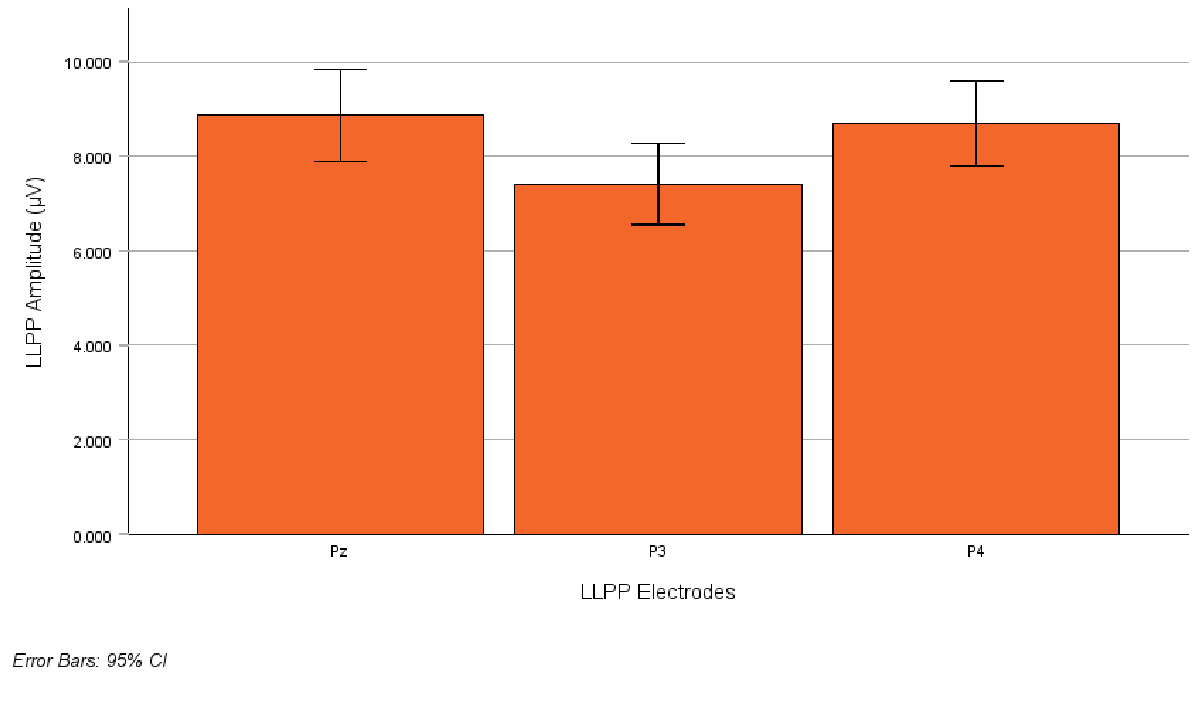
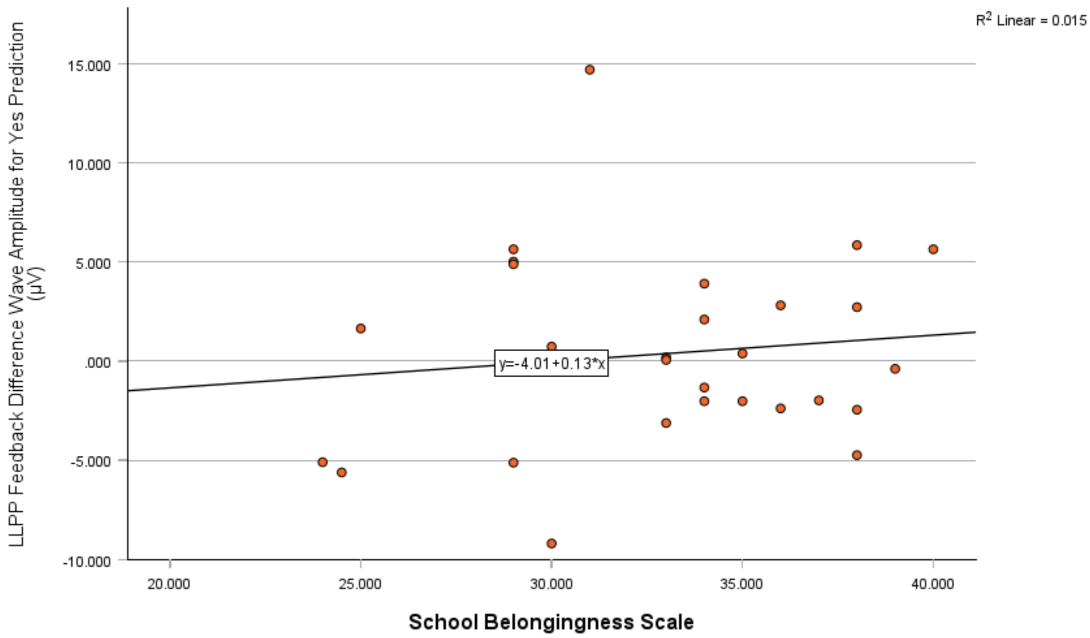


Figure 4.6.8.15 Averaged LLPP amplitudes by the electrodes

SBS and the LLPP

No main effect of the SBS scores on the LLPP was found, *F* (1, 24.000) = 1.123, *p* = .300. However, there was a significant interaction effect of Prediction Valence x Feedback Valence x SBS (congruency x SBS), *F* (1, 288.000) = 5.311, *p* = .022. To illustrate the LLPP and congruency relationship, we first computed the LLPP feedback difference wave amplitude by subtracting the LLPP amplitude for Yes Feedback from that for No Feedback (i.e. $LLPP_{NO}$-$LLPP_{YES}$). We separately calculated the LLPP feedback difference wave for Yes Prediction and No Prediction. The LLPP amplitude is positive; the larger the LLPP feedback difference wave, the greater the LLPP amplitude following No Feedback compared to Yes Feedback, resulting in a difference amplitude above zero and more positive. Subsequently, we constructed scatter plots depicting the relationship between the SBS and the LLPP feedback difference waves, one for Yes Prediction (Figure 4.6.8.16A) and another for No Prediction (Figure 4.6.8.16B). As shown in Figure 4.6.8.16A, when the prediction was positive, a larger SBS score corresponded to a larger LLPP feedback difference wave. In other words, after offering an acceptance prediction, there was a positive correlation between the LLPP feedback difference wave and the SBS score. In contrast, a negative association emerged between the LLPP feedback difference wave and the SBS score when the prediction was negative. In summary, based on the Prediction Valence, the SBS scores had opposing effects on the LLPP feedback difference wave amplitude. When predicting acceptance feedback, the more school belongingness one felt, the larger the LLPP after rejection compared to acceptance, leading to a difference amplitude above zero and more positive. Conversely, when predicting rejection feedback, the greater the feeling of school belongingness, the smaller the LLPP after rejection compared to acceptance, resulting in a difference amplitude below zero and more negative.

A



B

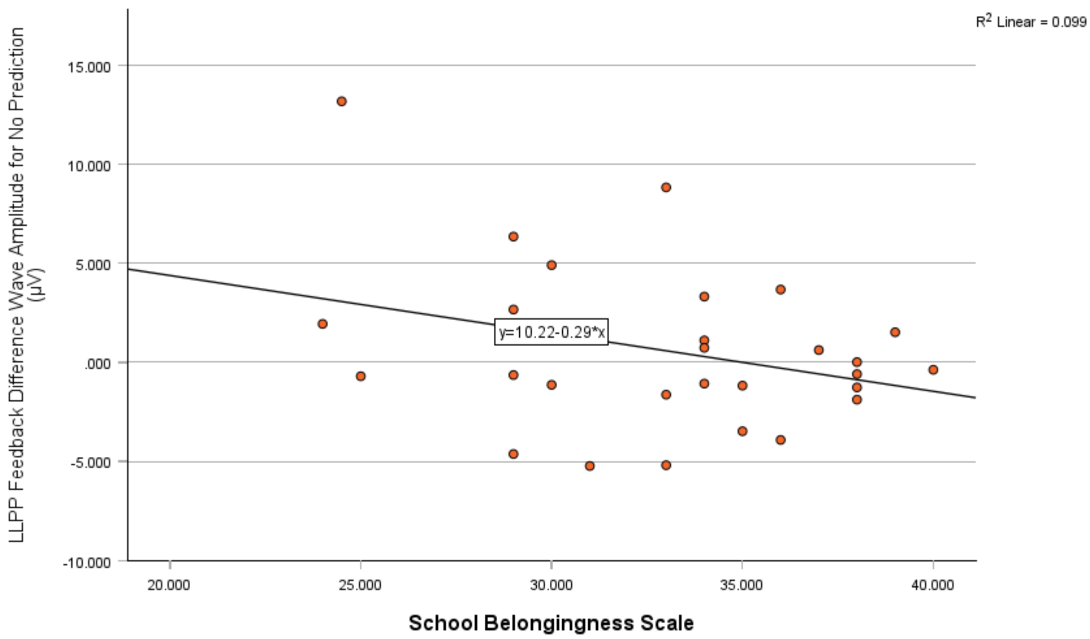
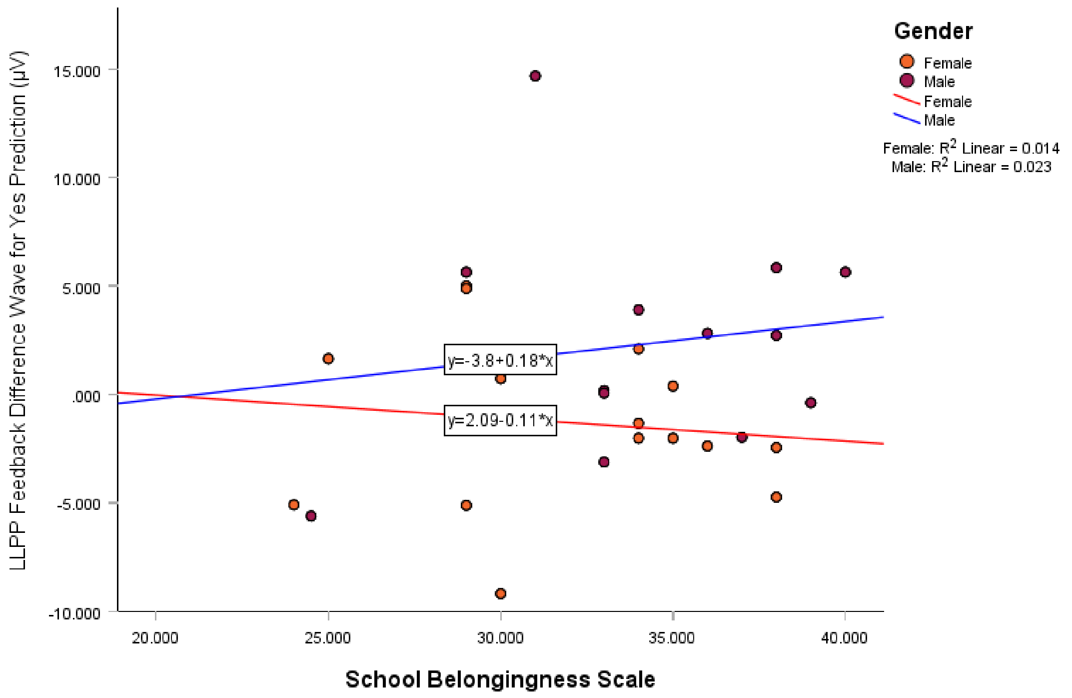


Figure 4.6.8.16 Correlation between SBS and the LLPP feedback difference amplitude

In addition, there were no significant interaction effects between the SBS scores and Prediction Valence or Feedback Valence. However, the interaction effect of gender and feedback valence was statistically significant. We also analysed the correlation between SBS and the LLPP feedback difference wave, segmented by gender. As illustrated in Figure 4.6.8.17, during instances of positive predictions, boys and girls exhibited opposite directions of correlation between the SBS and the LLPP feedback difference wave. Conversely, in scenarios involving negative predictions, both girls and boys demonstrated a negative correlation between the SBS scores and the LLPP feedback difference wave. An enhanced sense of belonging to the school was positively correlated with the prolonged regulation of emotions exhibited by the boy, as indicated by the LLPP, but this correlation was observed only in instances where the boy anticipated feedback regarding social acceptance.

A



B

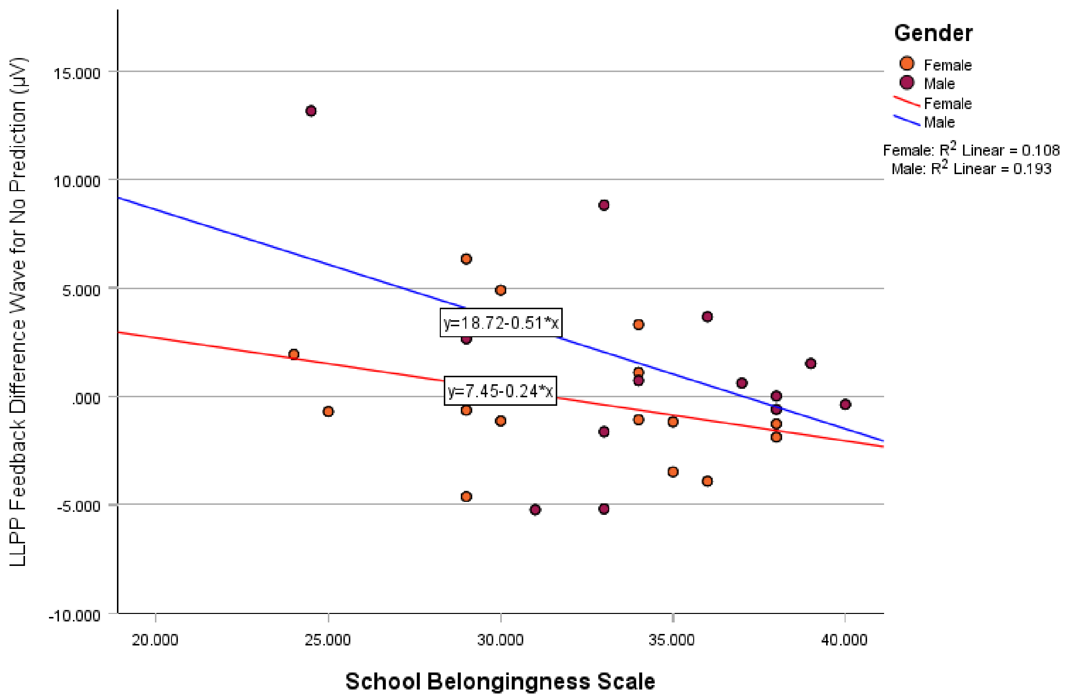


Figure 4.6.8.17 Correlation between SBS and the LLPP feedback difference amplitude by gender

In summary, the model revealed one significant main effect, the LLPP electrodes, and three significant interaction effects, including gender x feedback, prediction x feedback and congruency x SBS scores on the LLPP amplitude.

Chapter 5 Discussion

5.1 Introduction

The present study aimed to examine the emotional dynamics experienced by young children in the context of social exclusion. To this end, the study investigated the real-time self-reported predictions of the children during peer interactions, the neurophysiological correlates of the anticipation of social feedback, and post-hoc feedback appraisal in response to unfamiliar peers' social acceptance and exclusion. In particular, the study sought to: (1) investigate social anticipatory processes in primary school children, reflected in both self-report (i.e., real-time key presses of 'Yes' and 'No') and neural responses (i.e., SPN) during the anticipation of acceptance and rejection feedback from unknown peers; (2) delineate neural processes that unfold in response to social feedback. Specifically, they are processes related to immediate valence evaluation (i.e., FRN), sustained attention and memory (i.e., P3), and affective regulation (i.e., LPPs); (3) examine the relationship between these neural responses and individual differences in students' sense of school belongingness and the immediate distress that follows experiencing social exclusion from unfamiliar peers.

In this chapter, the findings from the empirical study will be examined in order to address three research questions. Regarding **Research Question 1**: What emotional experiences do young primary school children, aged 6 to 8 years, encounter when faced with social exclusion from other children, and how might these experiences influence their well-being? Section 2.2 of the literature review has provided several insights from existing research in response to Research Question 1. In addition, Section 5.2 of this chapter will focus exclusively on the relevant findings from this empirical study that address this inquiry. Subsequently, Section 5.3 will answer **Research Question 2**: What neural dynamics are involved in predicting and appraising social exclusion perpetrated by unfamiliar peers, and how do real-time neural processes correlate with a child's self-reported responses regarding immediate distress from social exclusion, and their sense of school belonging? Finally, Section 5.4 will address **Research Question 3**: What insights can be gained from the findings of multimodal data regarding the most effective strategies to assist primary school children in coping with the felt social and emotional consequences of social exclusion?

5.2 Social prediction, distress from exclusion and school belongingness

As outlined in Section 2.3, a novel conceptual framework concerning social exclusion has been introduced, grounded in a comprehensive and critical review of the existing literature. This newly developed framework incorporates the brain's predictive mechanisms, emphasising the affective processes that emerge during children's interactions with social environments. By integrating 'prediction' as a pivotal element of the conceptual model, this study expands the exploration of the emotional experiences encountered by young primary school children when confronted with social exclusion in educational settings. The present study moves beyond the conventional studies underpinned by the linear 'sense-think-act' model (e.g. Wesselmann & Williams, 2013) by incorporating 'social prediction' in the evaluation of the emotional experiences of individuals affected by social exclusion. In what follows, three key findings will be examined in order to address Research Question 1. First, young children demonstrate an optimism bias when predicting social feedback. Second, the immediate distress following exclusion by unfamiliar peers negatively correlates with the children's daily sense of belonging at school. Third, the capacity of self-reported data to probe the emotional experiences of young primary school children when confronted with social exclusion from other children is limited.

Finding 1

Young children who participated in the study demonstrated an optimism bias, indicating a higher level of anticipation in receiving acceptance rather than rejection feedback.

This finding is consistent with the results of prior research conducted with adult populations (e.g., Dekkers et al., 2015; Gunther Moor et al., 2010; van der Molen et al., 2014; van der Molen et al., 2017; van der Veen et al., 2016); however, it contrasts with findings from studies involving older children and adolescents, where no optimism prediction bias was identified (e.g., Gunther Moor et al., 2014; Topel et al., 2021). To the best of our knowledge, the present study is the first EEG study utilising the SJP with children under the age of eight; consequently, we faced significant challenges in directly comparing our results with those derived from equivalent age cohorts. The reasons underlying the observation that younger children in our study exhibited an optimism bias akin to that of adults, while older children and adolescents displayed a permissive bias on the same task, remain ambiguous.

A plausible explanation for the observed discrepancy between the younger participants in our study and adolescents regarding their prediction bias requires careful analysis. As discussed in Section 2.2, human beings possess an inherent desire for belonging, which manifests as an optimism bias in social exclusion experiments, as evidenced by our findings indicating an optimistic bias among young children. However, the changes involved in the transition from childhood to adolescence, marked by significant biological, neural, behavioural, and social transformations (Topel et al., 2021), may engender a relative negative shift in the optimistic prediction tendencies characteristic of childhood. Therefore, this general developmental transition may contribute to the observed disparities in prediction bias between young children and adolescents (e.g., Gunther Moor et al., 2014; Topel et al., 2021). However, this optimism bias may be specific to this cohort, which shares similar cultural backgrounds and value orientations, as they are nested within a chosen school context. As noted in 2.2.4, contextual factors significantly influence the subjective experiences of an excluded child (Sandstrom & Zakriski, 2004), and traditional models of social exclusion did not adequately incorporate this dimension within their research frameworks. A larger-scale study encompassing children and adolescents from diverse social contexts will facilitate the investigation of age-related trends associated with these biases in social prediction.

Finding 2

The immediate distress following exclusion by unfamiliar peers negatively correlates with a child's sense of belonging at school.

A significant negative correlation was identified between scores from the NTS and the SBS. This finding suggests that an increased sense of belonging within a child's own school is associated with a reduction in the immediate distress experienced following instances of peer social exclusion. This is particularly noteworthy in light of the fact that the images of the children that appeared on the screen during the experiment were unfamiliar to the participants. Also, the two questionnaires were completed with a minimum interval of one week. This finding suggests that a sense of belonging to one's own school may serve as a protective factor, thereby alleviating the distress related to social exclusion arising from interactions outside the school context.

This finding is consistent with recent research on the relationship between school belongingness and child wellbeing. In particular, as noted in 2.2.5, a sense of belonging within educational institutions has been shown to exert a positive influence on both the well-being of students and their academic performance and success (OECD, 2019; Štremfel et al., 2024). Research indicates that students' sense of belonging at school partially mediates the effects of bullying victimisation and bullying climate on academic performance (Huang, 2022). Furthermore, a recent study reveals that school belonging mediates the relationship between socioemotional well-being and loneliness among children of primary school age (Palikara et al., 2021). In addition, a recent investigation into the relationship between student perceptions of school climate and negative emotions concluded that a positive school climate, directly and indirectly, mitigates negative emotions, with school belonging and social avoidance serving as significant mediators (Chen et al., 2025). This study adds further evidence that school belongingness mitigates negative emotions from social exclusion experience. More practical implications of this finding will be addressed in 5.4.2 when discussing strategies to assist primary school children in coping with the emotional consequences of social exclusion.

Finding 3

The capacity of self-reported data to probe the emotional experiences that young primary school children encounter when confronted with social exclusion in school is limited, particularly its inability to capture the nuanced relationship between children's prediction bias and social distress that follows social exclusion.

Despite the observed correlation between the two self-reported data sets (i.e. NTS and SBS), no correlation was identified between these two data sets and prediction bias, a third self-report data set collected during the SJP task. The absence of a correlation between NTS scores and children's prediction bias is particularly intriguing, given that children's predictions were synchronously recorded while they engaged with the SJP and the NTS was completed immediately after the SJP. A negative association was observed between NTS and prediction bias scores, suggesting that more pessimistic predictions regarding acceptance may be associated with heightened distress following exclusion. However, this association did not attain statistical significance. Furthermore, no statistically significant correlation was observed between prediction bias and SBS scores.

One might contend that the study's limited sample size precluded the detection of correlations among the data. Alternatively, this result may confirm that self-reported data is not a reliable or precise measure of emotional experiences in young children in the context of social inclusion and exclusion (Kim et al., 2025). During the SJP experiment, children were asked to determine whether each child appearing on the screen had invited them to join the Minecraft team by pressing either 'Yes' or 'No' key button. The binomial category of 'Yes' and 'No' is not only a very gross measure of a person's prediction in any social situation but is also limited in indexing the extent of feelings the child was experiencing. Furthermore, the overt verbal or behavioural decisions of children, as registered in NTS, SBS and predictions during the SJP, may not be adequately informed by their neurophysiological and somatovisceral state (Duncan & Barrett, 2007; Barrett, 2018). In addition, following the overt prediction of 'Yes' or 'No', the brain persists in its anticipatory process until the child receives feedback from the other child while trying to maintain homeostasis and minimise prediction errors (Carvalho & Damasio, 2021; Damasio, 2018; Kim & Sankey, 2022). This continuous anticipatory process, partly modulated by the preceding overt decision, may be more important than overtly expressed decision in explaining the negative emotions a child experiences, as captured by the NTS. However, the self-report tools on their own fail to probe such data, warranting the multi-modal approach triangulating real-time neural processes with self-reported distress from social exclusion, plus children's sense of school belonging (Panksepp, 1988; Immordino-Yang & Gotlieb, 2017; Kim et al., 2025).

5.3 Social exclusion and neural dynamics within a predictive brain

As outlined in Section 2.2, it is crucial to recognise that emotional experiences in any social context involve both anticipatory and post-event processes. Contemporary neuroscience demonstrates that the brain is not a passive organ awaiting stimulation; instead, it actively anticipates, plans, and prepares the body to engage with the task, even before stimuli reach the sensory organs (Barrett & Simmons, 2015; Clark, 2013; Sterling, 2012). More specifically, the brain generates intrinsic activity, using 'Bayesian predictions' and continually updating itself based on perceived deviations from anticipated states (Barrett, 2017; Clark, 2016; Friston, 2012). From a predictive brain perspective, the brain consistently forecasts and prepares for forthcoming events, guiding the actions (Clark, 2016; Friston, 2012). This mechanism is essential for the survival and flourishing of individuals within their respective environments. The present study applied these ideas to the issue of social exclusion and investigated what neural dynamics are involved in anticipating social exclusion and the subsequent feedback appraisals. It also examined how these real-time neural processes correlate with self-reported immediate distress from social exclusion and daily feelings of belonging in the school environment (**Research Question 2**).

The EEG/ERP data from the present study adds evidence that distinctive neural processes are operating in the brain during both the anticipatory and post-feedback phases when children experience social inclusion and exclusion by peers. We found that children's conscious social prediction on whether the other peer has accepted them or not significantly modulated the neural activities of their brain at both phases. Furthermore, children's conscious social prediction modulated the relationship between these neural activities and self-reported levels of distress in the event of social exclusion by unfamiliar peers. The study also found that confirmed rejection, where a child's anticipation of rejection was confirmed by peer's rejection, evoked the most intense emotional responses among boys. It was also found that the sense of belonging within one's own school setting plays a crucial role in modulating the neural activities associated with the anticipation of social exclusion (e.g., SPN) and may also influence the extended emotional processes experienced by children (e.g., LLPP). Lastly, our findings imply that prediction error detection among young children may be slower than in adults. The subsequent two sections will present details of findings from two phases of neural and affective processes (anticipatory vs. post-hoc feedback appraisal).

5.3.1 The anticipatory process

The key ERP component studied for the anticipatory process is the SPN, and the following three critical findings were identified.

EEG Finding 1

Children's conscious social prediction on whether the other child has accepted them or not modulates the anticipatory neural activities of their brain.

The results of the MEM analysis demonstrated that children's conscious social prediction of whether or not the other child has accepted them modulates the anticipatory neural activities of their brain, as indexed by the amplitudes of the SPN (see 4.6.3). While the difference was not great, the SPN amplitudes following a 'No' prediction were found to be greater than those following a 'Yes' (F (1, 300) =5.976, p=.015), when all other effects were taken into account. This finding is consistent with *existing* studies on the relationship between SPN amplitudes and the emotional valence of following stimuli. As documented by Michalowski et al. (2015), SPN amplitudes observed in anticipation of unpleasant images are markedly larger than those observed in anticipation of neutral images. Furthermore, the SPN under uncertain threats differs from that under safety or certain threats (Tanovic et al., 2018; Tanovic & Joormann, 2019). In the present study, the anticipation of rejection presents an uncertain threat, while the anticipation of acceptance may provide a sense of safety, thereby reducing the amplitude of SPN in young children.

However, it is important to note that the existing body of literature on SPN identified from the SJP studies provides equivocal results regarding the impact of conscious predictions on the modulation of anticipatory neural processes. Van der Molen et al. (2014) showed that, in adults, the expectation of social acceptance, rather than rejection, significantly heightened the SPN amplitudes associated with the anticipation of social feedback. This contrasts the results observed in this study conducted with young primary school children, which showed the opposite pattern of SPN amplitudes. A study by Tople et al. (2021) did not replicate a similar effect in the adolescent group. Additionally, the study by Tople et al. (2021) did not exhibit a conclusive SPN pattern associated with conscious social prediction. These inconsistent findings from the SJP studies suggest that the valence of social prediction is an important, but not the only, factor that modulates the neural process involved in anticipating social feedback. There is a notable age difference across the cohorts in those three studies, suggesting that there may be age-related developmental changes in the impacts of prediction valence. In addition, gender may also play a role in this inconsistency, as the study conducted by Van der Molen et al. (2014) included only female adult participants, while our study comprised participants of both genders. It is recommended that future research investigates the impacts of other factors than the valence of prediction itself more extensively.

EEG Finding 2

A child's prediction of acceptance or rejection modulates the relationship between the anticipation of social feedback and the immediate distress that follows experiencing social exclusion from unfamiliar peers.

The findings of the present study indicated that increased SPN associated with the anticipation of social exclusion correlated with a reduction in the immediate distress (i.e. smaller NTS scores) experienced by children following instances of social exclusion from unfamiliar peers. In other words, children who deploy greater neural inhibitory processes (more negativity) during the anticipation phase, particularly after predicting social rejection, tend to exhibit diminished levels of distress after being excluded by unfamiliar peers. This observation suggests that heightened neural inhibition in anticipation of negative social feedback may function as a short-term protective factor, thereby mitigating the immediate distress associated with social exclusion among young children. This hypothesis is further substantiated by an analysis of what the SPN constitutes. The SPN belongs to a class of slow cortical potentials (SCPs) and manifests predominantly in anticipation of stimuli characterised by affective or motivational valence (Böcker et al., 2001; Van Boxtel, 1994; Böcker and Van Boxtel, 1997). The SPN is not related to motor preparation; rather, it is interpreted as a manifestation of control over response timing and attention to the anticipated stimuli (Böcker et al., 2001). Kotani and colleagues (2009) argue that SPN indexes "the awareness of interoceptive information that precedes feedback stimuli" (p. 75). Therefore, children whose SPN amplitude is greater after predicting rejection may be better prepared to encounter negative social feedback with relatively heightened interoceptive awareness.

However, the present study contends that this increased interoceptive awareness prior to the negative social feedback may result from long-term detrimental experiences that impact the child's overall well-being and development. The subsequent analysis of the relationship between SPN amplitudes and children's sense of school belonging supports this contention.

EEG Finding 3

A child's school belongingness modulates the anticipation of social feedback.

Our research has revealed a significant influence of a child's sense of belonging within the school environment on the anticipation of social feedback. Children exhibiting lower levels of school belongingness tend to exhibit increased SPN following the anticipation of receiving rejection feedback. This observation suggests that these children may be more predisposed to heightened vigilance and attention in anticipation of negative social feedback and may recruit additional interoceptive awareness during the anticipation phase when expecting rejection as opposed to anticipating acceptance. Conversely, children who feel a greater sense of belonging within the educational environment may exhibit reduced vigilance and necessitate less awareness of interoceptive information in anticipation of negative social feedback. Research has demonstrated that a heightened sense of school belonging serves as a protective factor for students' well-being (Huang, 2022; OECD, 2019; Štremfel et al., 2024), and this study contributes to the evidence base by demonstrating that these protective impacts may operate at a neural level.

Research into anticipatory processing in populations with affective disorders can help us understand the link between SPN and feelings of belonging at school. Topel and his colleagues (2021) found that the neural activities associated with the anticipation of social feedback were markedly greater among adolescents displaying heightened levels of social anxiety, irrespective of whether the anticipated feedback was positive or negative. Furthermore, their findings revealed that the influence of social anxiety on neural activities related to the anticipation of social exclusion was particularly significant for females as opposed to males (Topel et al., 2021). Van der Molen et al. (2014) also discovered that individuals exhibiting elevated fear of negative evaluation demonstrated increased neural activities in anticipation of positive social feedback. This suggests that students who lack a positive sense of school belonging may exhibit neural anticipatory processes similar to those with social anxiety when anticipating potential rejection from another child.

In conclusion, the importance of social prediction is paramount. A child's anticipation of social acceptance or rejection profoundly influences the neural activities that underlie the anticipation of social feedback. Furthermore, it modifies the relationship between these neural activities and the immediate distress experienced following social exclusion by unfamiliar peers. Importantly, the protective impacts of a child's sense of belonging within their own school operate at a neural level. Our findings suggest that this sense of belonging might serve as a mitigating factor, reducing excessive interoceptive awareness when they anticipate social rejection from unfamiliar peers.

It is imperative to comprehend the neural dynamics underlying the anticipation of social feedback in children to assess their social and emotional well-being within educational contexts. However, there is a dearth of research that specifically examines how young children anticipate social feedback and the subsequent impact of social predictions on their well-being, especially in school contexts. This study aimed to address this gap by undertaking a pioneering investigation into the neural underpinnings of anticipating social exclusion in children under eight, utilising the SJP. Additionally, it explored the influence of children's sense of school belonging on these neural dynamics. In light of the developmental trajectories and gender disparities identified in the anticipation of social feedback, it is recommended that future research encompass a more extensive age range. In addition, future research endeavours could explore the relationship between school belongingness and its interaction with social predictions relevant to the anticipation of social feedback, employing a broader sample cohort. Finally, there exists a limited number of intervention programmes that focus on the implications of victims' expectations concerning social feedback and its overall impact on their well-being. Therefore, it is recommended that future interventions integrate this dimension to provide more comprehensive support.

5.3.2 The post-hoc feedback appraisal processes

This section continues to respond to **Research Question 2** by elaborating the four key findings on the post-hoc feedback appraisal phase of neural dynamics captured with the SJP experiment, with a particular emphasis on the influence of prediction valence and feedback valence on these neural activities and the significance of prediction-feedback congruency within this context. Furthermore, the discussion will encompass notable findings related to the association between post-hoc feedback appraisals and the immediate distress experienced by students following social exclusion by unfamiliar peers. In addition, we will examine important findings regarding the impact of a sense of belonging within the school environment on post-hoc feedback appraisals. The key ERP components studied for the post-hoc feedback appraisal process and their time windows are summarised in Table 5.3.2.1.

Table 5.3.2.1 Feedback-related ERPs

ERPs	Time windows	Neural mechanisms
FRN	FRN 250 – 350 ms	The immediate post-hoc feedback appraisal, more specifically, valence processing of social-evaluative feedback
P3 (P3a/P3b)	P3a 280 – 500 ms P3b 425 – 650 ms	P3a: the early detection of prediction error/ attention and memory operations P3b: attention and memory operations
LPPs (LPP/LLPP)	LPP 800 – 1000 ms LLPP 1000 – 2000 ms	Sustained emotional regulation process

EEG Finding 4

A child's social predictions have a significant impact on their neural activities related to the immediate post-hoc feedback appraisal, as indexed by FRN. A child's social predictions play a crucial role in moderating the relationship between young children's immediate post-hoc feedback appraisal and their perceived exclusion distress, more so than the actual feedback received. Furthermore, a child's sense of school belonging marginally modulates the relationship between their social prediction and the immediate post-hoc feedback appraisal.

A significant main effect of prediction valence on the amplitude of the FRN has been observed. Specifically, the amplitude of the FRN following a rejection prediction is notably greater than that observed following an acceptance prediction. This finding indicates that a child's conscious social prediction may not only influence the anticipatory processes occurring before receiving social feedback (see discussion in the previous section) but also affect the immediate neural dynamics that respond to peers' social feedback. The extant literature employing the SJP posits that the FRN serves as an index for the valence processing of social-evaluative feedback (Dekkers et al., 2015; Kortink et al., 2018; Van der Molen et al., 2014). Within this discipline, researchers frequently focus on exploring the impact of social feedback itself (Van der Molen et al., 2014) or the congruence/incongruence between social predictions and feedback in relation to these evaluative processes (Dekkers et al., 2015; Gu et al., 2020; Kortink et al., 2018; van der Molen et al., 2017; van der Molen et al., 2018; van der Veen et al., 2016). The present research makes a contribution to the existing literature by highlighting the effect of social predictions on the immediate post-hoc feedback appraisal. In summary, even before a child becomes consciously aware of it, the child's own prediction that precedes the actual inclusion/exclusion incident instantaneously may influence their neural evaluation of the feedback valence they received.

Furthermore, we identified a significant interaction between prediction valence and the immediate distress experienced following social exclusion by unfamiliar peers on the FRN. Specifically, the findings indicated that an increased amplitude of the FRN after the expectation of rejection was associated with a diminished level of distress among participants after encountering exclusion by unfamiliar peers. This observation suggests that heightened neural activity associated with the immediate post-hoc feedback appraisal, as indicated by the enhanced FRN, following the anticipation of negative social feedback may assist young children in alleviating the immediate distress related to social exclusion. Contrary to the expectation, no significant interaction effect between feedback valence and exclusion distress on the FRN was identified. In other words, the relationship between the neural activities that underpin immediate social feedback appraisal and the child's perceived exclusion distress remained constant, irrespective of the nature of the feedback received—whether acceptance or rejection. These findings indicate that social prediction could potentially plays a crucial role in moderating the relationship between young children's immediate post-hoc feedback appraisal and their perceived exclusion distress, more so than the actual feedback received.

From a predictive-processing perspective, the brain undergoes preparation in anticipation of actual social exclusion, being informed by homeostatic feelings or core affect, contextual factors (e.g. facial expressions by unfamiliar peers from an online gaming team), and prior experiences in analogous situations. As previously discussed, a child's social prediction influences various subsequent neurobiological functioning that follow. This elucidates the significant influence of children's social predictions on neural activities associated with the anticipation of social feedback (e.g., SPN) and the immediate post-hoc feedback appraisal (e.g., FRN). Furthermore, as elaborated in our conceptual framework, the anticipation of social exclusion infringes upon our fundamental value of belonging, which manifests as a spectrum of physiological changes within our bodies. These bodily alterations become evident in our brains via homeostatic feelings or core affect, such as negative core affect or heightened arousal, reflecting a continuous dialogue between the body and the brain, driven by homeostatic needs. In essence, the experience of social exclusion evokes feelings of 'badness', which may propel us to exert tremendous effort in restoring homeostasis. This phenomenon may elucidate the observations that, following predictions of social rejection, there is a concomitant increase in neural activities related to the anticipation of social feedback (e.g., SPN) and immediate post-hoc feedback appraisal (e.g., FRN) that correspond with a reduction in immediate social distress experienced after incidents of exclusion by unfamiliar peers.

Furthermore, a marginally significant interaction effect between social prediction and school belongingness on the FRN was observed. Similar to the SPN, we found that an increased sense of school belonging was found to be correlated with a diminished amplitude of the FRN following the anticipation of social rejection. To rephrase, heightened levels of school belonging were associated with reduced neural activity related to the anticipation of social feedback (e.g., SPN) and the immediate valence appraisal that follows the actual feedback (e.g., FRN), when a child was anticipating social rejection. The diminished neural activity observed during the immediate post-hoc feedback appraisal after negative social prediction among participants with a higher level of school belonging might suggest that a sense of belonging to one's own school is a protective factor against social exclusion. Children possessing a stronger sense of school belonging may exhibit reduced valence evaluation during the immediate post-hoc feedback appraisal phase. Collectively, these findings provide empirical support for the conceptual framework that has been established to delineate the emotional dynamics of social exclusion.

EEG Finding 5

The detection of prediction error in the brains of children who experience social inclusion and exclusion may occur in a later time window in comparison to adults.

The present study found no significant effect of feedback valence (i.e. 'yes', 'no') on the FRN, consistent with van der Molen et al. (2014). Our finding contradicts the consensus that the FRN is responsive to feedback valence, typically exhibiting a more pronounced reaction to negative feedback than positive feedback, as detailed in Ullsperger et al. (2014). One potential explanation for this lack of differentiation could be the current experimental paradigm, where participants predict social feedback prior to its onset. Indeed, it was the social predictions that had significantly influenced the FRN; specifically, the anticipation of social rejection notably elevated the FRN. This implies that, in the context of social exclusion, a child's own conscious prediction modulates the immediate valence processing of the brain after receiving social feedback more so than the message of actual feedback.

Furthermore, our study did not reveal a statistically significant effect of prediction-feedback congruency on the FRN amplitude. This is in contrast with the extant SJP literature on adults, which consistently demonstrates that the FRN is more pronounced in response to incongruent feedback (e.g., Dekkers et al., 2015; Kortink et al., 2018). In addition, no significant effects were observed on the P3a and P3b components, contradicting previous findings in adult populations that indicate a main effect on P3 (e.g., Dekkers et al., 2015; Kortink et al., 2018). In summary, these results indicate a lack of significant impact of prediction-feedback congruency on both the FRN and P3 components in young children, diverging from the conclusions drawn in adult SJP research.

The observed discrepancy between the findings of this study and those of adult participants may be attributable to several factors. Firstly, the discrepancy may stem from the differing developmental status of young children's brains compared to those of adults. While adults' value systems also regard social exclusion as detrimental and elicit negative responses akin to those of young children, their relatively mature brains and enhanced cognitive capacity enable them to regulate these changes to restore homeostasis more effectively. This enhanced capacity in adults may enable them to allocate neural resources to evaluate the congruence and incongruence between social predictions and feedback. However, this capacity is not fully fledged in young children. Children's brains are constrained in their neural capacities, which are predominantly directed towards addressing interoceptive signals from bodily and affective changes, particularly those arising from their own social predictions. This may result in young children's brains focusing on addressing interoceptive signals rather than engaging in evaluating congruence or incongruence between social predictions and feedback as adults do. Secondly, findings from different ERP components suggest that young children may require more time than adults to process congruency. This interpretation is supported by evidence demonstrating the lack of a significant main effect of congruency on feedback-related ERPs before 1000 milliseconds (e.g., P3a, P3b, and LPP), not just FRN. It was only after 1000 to 2000 milliseconds that congruency exhibited a significant effect on LLPP. This finding indicates that the neural processing of congruency occurs within the LLPP time window (1000 – 2000 ms) in young children, suggesting that the detection of prediction errors (Dekkers et al., 2015) or unexpected outcomes (van der Veen et al., 2016) is postponed in children compared to adults who are more proficient at identifying these errors promptly within the FRN time window (250 -350 ms).

The present findings significantly enhance the current body of literature on the developmental differences in the immediate post-hoc feedback appraisal (as indicated by FRN), as well as attention and memory update (as indexed by P3) that follows social feedback (Polich, 2007), between young children and adults. Additionally, the findings suggest that young children might require more time than adults to detect predictor errors. However, it is essential to note that these interpretations remain tentative and certainly preliminary, as they are derived from a single study involving a specific cohort of children. These findings concerning the impact of prediction-feedback congruency on the feedback-related ERPs offer additional evidence that validates our conceptual framework of social exclusion, emphasising the critical contribution of the Prediction-Feedback cycle. It is recommended that future research consider engaging a sample with a broader age range in order to further chart the neural development trends associated with post-hoc social feedback appraisal and prediction error detection in social exclusion.

EEG Finding 6

Social prediction and feedback congruency made a significant influence on sustained emotional processes (e.g., LLPP), indicating that the processing of prediction errors occurs predominantly in a relatively late time window in young children. Furthermore, the confirmed rejection elicited the most substantial emotional regulatory processes among the boys.

A substantial prediction-feedback congruency effect was identified on the LLPP, but not on the LPP. Specifically, the LLPP amplitudes elicited by confirmed social rejection (NN) were significantly larger than those elicited by confirmed social acceptance (YY). Further analysis demonstrated that this effect was primarily observable from the male participants, as a significant difference in LLPP amplitudes between confirmed rejection (NN) and confirmed acceptance (YY) was exclusively observed among the boys. In contrast, no significant differences in LLPP amplitudes were observed among the female subjects across the four congruency types.

As documented in the extant literature, the LPP is sensitive to the valence of stimuli, exhibiting a greater degree of prominence in response to emotional stimuli (e.g. pleasant or unpleasant) as compared to neutral stimuli (see Section 2.4.3). Moreover, the LPPs have also been recognised as a neural indicator of cognitive reappraisal in children engaging in cognitive reappraisal tasks (Babkirk et al., 2015; Dennis & Hajcak, 2009; Van Cauwenberge et al., 2017). There is a general consensus that the LPPs indicate prolonged emotional processing. The present findings on LLPP are consistent with known profiles of late positive potentials. Anticipated rejection (i.e. unpleasant stimuli) provoked the most potent emotional regulatory processes, while anticipated acceptance (i.e. pleasant stimuli) elicited the least vigorous responses, exclusively among the boys. In contrast, the girls demonstrated reduced sensitivity to the type of congruence during their regulatory processes after receiving social feedback. In other words, when a boy's expectation of rejection was confirmed, they experienced intensified emotional regulation processes. The present findings significantly contribute to the existing literature by demonstrating the importance of social prediction on children's emotional dynamics in the context of social exclusion.

In conclusion, prediction-feedback congruency exerts a significant influence on sustained emotional processes, as demonstrated by the LLPP during the 1000 to 2000 milliseconds following feedback onset. This finding suggests the processing of prediction errors becomes more pronounced at a later time in young children, compared to adults. Furthermore, the confirmed rejection elicited the most substantial emotional regulatory responses among the boys, which suggests that it is critical to include social prediction in consideration when investigating emotional dynamics in children within the context of social exclusion, rather than solely focusing on the effect of social feedback.

EEG Finding 7

A heightened sense of school belonging was found to be positively correlated with the boys' prolonged emotion regulation of social exclusion, but only in instances where they anticipated social acceptance feedback. Conversely, when social rejection was anticipated, a heightened sense of school belonging was found to be negatively associated with children's prolonged emotion regulation of social exclusion.

Our findings indicate a significant interaction between prediction-feedback congruency and school belongingness on the LLPP within 1000 to 2000 ms following feedback onset. Specifically, when the prediction was positive, a heightened sense of belonging within the school environment, as experienced by the child during their daily school life, was positively correlated with an increased LLPP following the reception of rejection feedback. Conversely, in instances where the prediction was negative, a heightened sense of belonging was found to be associated with a diminished amplitude of LLPP following instances of social rejection feedback. Further analyses revealed gender differences influencing this interaction effect on the LLPP.

For girls, an enhanced sense of belonging within the school environment was associated with a decreased LLPP following the receipt of rejection feedback, in contrast to acceptance feedback, regardless of the prediction of acceptance or rejection. Conversely, for boys, in scenarios of anticipated rejection, a heightened sense of belonging to the school correlated with a reduced LLPP upon receiving rejection feedback compared to acceptance feedback. Conversely, when anticipating acceptance, boys with an elevated sense of school belonging tend to show an elevated LLPP amplitude following rejection feedback. To summarise, the present study found that, in anticipation of social rejection, a heightened sense of school belonging was associated with a diminished LLPP following social rejection, consistent across both genders. Conversely, in anticipation of social acceptance, the influence of school belonging on LLPP exhibited contrasting effects between boys and girls.

The increased LPP in young children in response to negative stimuli is a valid indicator of their cognitive appraisal maturation (Cheng et al., 2014; Hajcak et al., 2010). In other words, larger LPPs in young children indicate superior emotion regulation. This stands in contrast to adults, whose larger LPPs are indicative of less efficient emotion regulation in response to negative social feedback (Kujawa et al., 2013; Cheng et al., 2014). Consequently, the reduced LLPP observed in our study, in the context of rejection anticipation, signifies children's less effective emotion regulation of social feedback, even when children exhibited a strong sense of school belonging. Conversely, in situations where acceptance was anticipated, male students who showed a heightened sense of school belonging exhibited an improved process of emotion regulation. This finding suggests that the protective effects of children's sense of school belonging are still moderated by children's own anticipation of rejection and acceptance. Therefore, it once again provides empirical evidence that supports our conceptual framework of social exclusion, emphasising the importance of adding a prediction-feedback cycle in the emotional dynamics of victims.

Furthermore, in relation to the relationship between post-feedback neural processes and school belongingness, it was observed that school belongingness exhibited a significant interaction effect with prediction-feedback congruency exclusively in the latter emotional processes captured by the LLPP. Relatively earlier processes, such as valence evaluative processes indicated by the FRN, attention and memory related processes represented by the P3, did not show such an interaction effect. This finding suggests that a child's sense of belonging at school may not significantly affect the earlier feedback-related processes; rather, its influence becomes evident only in the later stages of emotional regulation. The present findings emphasise the importance of leveraging the high temporal resolution afforded by EEG methodology to capture real-time neural mechanisms in social and emotional development. Conventional research methods, such as questionnaires and observations, are unable to provide the level of fine details afforded by this methodology.

In conclusion, a child's social prediction regarding whether they will be accepted or rejected exerts a significant influence on their own emotional processes in the brain, as well as on the extent of protective impacts that their sense of school belonging can have. A child's social prediction regarding acceptance or rejection significantly impacts the anticipation of social feedback (SPN) and the immediate post-hoc feedback appraisal (FRN). Furthermore, social prediction moderates the relationship between the anticipation of social feedback (SPN) and the immediate emotional distress that follows experiences of social exclusion from unfamiliar peers. It also markedly alters the interaction between the immediate post-hoc feedback appraisal (FRN) and distress resulting from social exclusion. Additionally, it was children's prediction of rejection that moderated the positive association between young children's sense of school belonging and their adaptive emotional regulation. Consequently, an exclusive focus on social feedback prevalent in current social rejection studies may overlook a critical parameter that operates in the emotional dynamics in the context of social exclusion among young children. Furthermore, the absence of a notable influence of prediction-feedback congruency on early post-feedback potentials, including FRN, P3a, P3b, and LPP, may imply that prediction error detection in young children's brains occurs at a much later time, such as the LLPP time window, which is later than that observed in adults.

5.4 Towards a predictive brain informed research and intervention framework for social exclusion

This section addresses **Research Question 3**: What insights can be gained from the findings of multimodal data regarding the most effective strategies to assist primary school children in coping with the felt social and emotional consequences of social exclusion? We will approach this inquiry by suggesting that our newly developed conceptual framework for social exclusion serves as a foundational model for future research and intervention efforts. In Section 5.4.1, we will provide empirical support for our model, specifically examining the current study's findings that reinforce the framework's three core assumptions. Validating this conceptual framework will establish a basis for our subsequent recommendations for practice (Section 5.4.2).

5.4.1 The empirical validation of the conceptual framework on social exclusion

As outlined in Section 2.3, our framework builds on the biopsychosocial framework for affective processing established by Immordino-Yang and Gotlieb (2017). However, their model has some limitations. For example, its account of emotional development does not incorporate the brain's 'predictive' processing, nor does it offer detailed insights into 'real-time' and 'here-and-now' affective processes that emerge as children interact with social environments. To address these limitations, we have developed a new and improved framework that incorporates 'feedback loops' at the intersection of the predictive, embodied brain and immediate contexts (Kim & Sankey, 2022). It also incorporates fundamental principles derived from the 'predictive brain' to elucidate how the anticipatory mechanisms of the brain significantly influence the emotional dynamics experienced by victims of social exclusion, wherein prior experiences shape an individual's expectations when confronted with the possibility of further exclusion. Furthermore, drawing upon the literature reviews in Sections 2.1 and 2.2, our conceptual framework regarding social exclusion articulates three assumptions. The preceding sections have demonstrated how specific findings from this empirical school-based study substantiate our conceptual framework on social exclusion. In the forthcoming section, we will highlight a few findings to illustrate how these findings support the three core assumptions from our conceptual framework of social exclusion.

The first assumption underpinning the framework is that humans are inherently social beings with a profound longing for belonging, a fundamental biological value that has evolved over time. The following findings from the present study lend support to this claim. Firstly, young children in our study exhibited an optimism bias, indicating a higher perceived likelihood of receiving acceptance rather than rejection feedback. In other words, young children intuitively anticipate more social acceptance due to the inherent desire for belonging. As previously discussed, feelings of 'badness' are associated not only with actual experience but also with the anticipation of social exclusion. This 'badness' may, in turn, propel an individual to exert tremendous effort in restoring homeostasis. This hypothesis is further substantiated by the observation that the anticipation of negative social feedback has been shown to induce heightened interoceptive awareness (e.g., SPN) and immediate post-feedback appraisal (e.g., FRN). These phenomena correspond with a reduction in immediate social distress experienced after incidents of exclusion by unfamiliar peers.

The second assumption of the framework is that the brain constructs and employs an internal Bayesian model of the world (Friston, 2012), shaped by prior experiences and tailored to meet allostatic requirements. Barrett (2017) argues this internal model is represented as 'concepts', which are imbued with value and enable the brain to anticipate future stimuli. The findings on the interplay between school belonging and prediction valence concerning the neural mechanisms underlying immediate post-hoc feedback appraisal provide supplementary evidence to support this assumption. The history of a child's experience at her own school establishes a model of peer interactions, which contributes to the shaping of new predictions whenever the child engages in new social interactions. The quality of this model, with a comprehensive evaluation of all past encounters, both positive and negative, can facilitate the development of a child's anticipation and ability to respond to the consequences. Consequently, the observation that school belonging functions as a protective factor, thereby mitigating the distress associated with social exclusion, is not unexpected.

This finding also supports our third assumption, which posits that emotions and social exclusion function as dynamic systems in accordance with the principles outlined in DST. Within the context of the social exclusion experiment conducted in this study, school belonging, which encapsulates ‘past’ experiences or concepts related to social exclusion, alongside the ‘here-and-now’ social prediction and various additional components within this complex dynamic system, constitutes the elements from which the neural dynamics emerge and self-organise.

Despite its modest scope, the present study has demonstrated that an exclusive focus on social feedback and over-reliance on self-report and behavioural measures, as prevalent in current social rejection studies, overlook a critical parameter that operates in the emotional dynamics in the context of social exclusion among young children. Drawing on critical insights from the DST and the Predictive Brain framework, this study has demonstrated that a child’s social prediction regarding whether they will be accepted or rejected exerts a significant influence on their own emotional dynamics and well-being. It is contended that the conceptual framework offered in this study can serve as a useful framework to inform subsequent studies and interventions on social exclusion.

5.4.2 Implications for practice

In light of the findings elucidated in the present study and our enriched conceptual framework of social exclusion, we hereby propose a series of recommendations to furnish practical strategies for assisting primary school children in managing the emotional consequences of social exclusion (Research Question 3). In accordance with our conceptual model of social exclusion, we posit that social exclusion operates as a dynamic system. The dynamic interaction among its components, including individuals (e.g., their physical bodies, embodied brains) and both immediate and broader societal contexts, underscores the integrated nature of the overarching phenomenon of social exclusion. Empirical evidence from our previously discussed research findings supports this model. It is proposed that intervention programmes should adopt a holistic approach as offered by this conceptual model to improve the ecological validity of the intervention. The following section will present proposed strategies at individual and educational institutional levels. At the individual level, we advocate for transitioning from a 'reactive' to a 'predictive' approach, such as implementing interoception awareness programmes in the classroom and enhancing students' sense of school belonging. At the institutional level, we recommend updating teacher training programmes and expanding the learning areas within the curriculum that are conducive to children's holistic development.

Shifting from a 'reactive' to a 'predictive' approach

The findings from this study indicate that children's conscious social prediction modulates the neural activities underlying the anticipation of social exclusion and subsequent feedback appraisals. Furthermore, our findings underscore the influence of children's social prediction on their social and emotional well-being. However, the traditional linear 'sense-think-act' model that is pervasive in social exclusion theory still underpins many current intervention programmes for victims of social exclusion or covert bullying. Consequently, these programmes frequently adopt a similar linear approach, addressing post-exclusion issues such as emotional and psychological responses and coping strategies, without considering the impact of victims' preceding anticipation of social feedback on their overall well-being and the subsequent emotional challenges when encountering social exclusion. It is recommended that future interventions incorporate this dimension to provide more comprehensive support.

In order to transition from a reactive to a predictive approach, it is first necessary to provide children with opportunities to learn how their brains make predictions. This will help them become more aware of their own unhealthy biases and misinformed expectations. By recognising their brain's predictive natures, they will be better equipped to shape or reshape their social decision-making. This process necessitates the cultivation of an understanding of the pivotal role of the body in our mental life and the inherent interconnectedness between the body and the brain, thereby positioning the body as a central element in intervention strategies. As previously discussed, core affect/homeostatic feeling emerges from interoceptive sensations and constitutes a foundational element in the construction of all mental experiences (Barrett, 2018; Damasio, 2018; Damasio & Damasio, 2023). Furthermore, these biological mechanisms play a vital role in the Prediction-Feedback cycle. It is evident that children need to learn how their bodily sensations can both inform and misguide their social decision-making and how to perceive their social world more closely to reality rather than through a lens of fear or anxiety.

A strategy that has been identified as having potential for implementation in the classroom environment is to assist children in developing interoceptive awareness by enhancing their sense of mind-body connections. It is an inescapable reality that individuals who experience social exclusion feel 'bad' (e.g., negative homeostatic feelings and heightened arousal) at the neurobiological level, as social exclusion fundamentally undermines our inherent need for belonging. This sense of 'badness' often manifests in physiological symptoms (e.g., an elevated heart rate and increased muscle tension). Research indicates that an individual's perception of their body and its associated signals facilitates more effective adjustments to their emotional states, while enhanced interoceptive awareness aids in the downregulation of emotions (Füstös et al., 2013). Teachers can support victims of social exclusion by first helping them develop interoceptive awareness through simple body check-ins, where students identify bodily sensations and then guide them to calm the heightened arousal through deep breathing, gentle movement, or other mindfulness practices. Or they can create a 'Feelings Thermometer' visual where students can point to their emotional intensity level and practice the 'Stop-Breath-Notice-Choose' technique when feeling excluded. Initiatives to cultivate interoceptive awareness have been implemented in schools and have demonstrated efficacy. For example, the Department for Education in South Australia has initiated a pilot teaching programme, integrating interoception instruction as a proactive, positive behaviour management approach in over 250 schools. This initiative aims to promote self-regulation and mitigate challenging behaviours (Goodall, 2025). The Government of South Australia (2025) has delineated several advantages of integrating interoceptive skills within the classroom, including assisting students in connecting with and comprehending their bodies and emotions, fostering a sense of belonging and reducing behavioural challenges in schools.

Secondly, to adopt a predictive approach to social exclusion intervention, we recommend enhancing students' sense of belonging as an essential component of social exclusion intervention programmes. Our research indicates that a sense of belonging within the school environment significantly influences children's anticipation of social exclusion and impacts their emotional regulation in response to such experiences. Furthermore, a sense of belonging may function as a protective factor, mitigating the distress associated with social exclusion that can arise from interactions beyond the school context. These findings underscore the critical importance of nurturing students' sense of belonging in educational settings as an integral part of interventions addressing social exclusion. Moreover, as previously discussed, the sense of belonging that students experience within their school constitutes a part of their internal model of the world, especially relating to concepts associated with social interactions (e.g., social exclusion). These past experiences and concepts are crucial when constructing mental experiences, encompassing emotions within the context of social exclusion. From a predictive brain perspective, enhancing students' sense of belonging in school fundamentally modifies and redefines their concepts related to their social experiences within the academic setting in a favourable manner. Consequently, with this revised internal model, students are more predisposed to experience social exclusion in a more positive light or to cope more effectively with emotional and social challenges. Teachers can create daily "Belonging Rituals," such as morning greeting circles, where each student receives personalised acknowledgment. This helps establish predictable positive social feedback loops that reinforce students' sense of belonging. Additionally, teachers can set up "Predictive Welcome Boards" that display photos, interests, and contributions of students and their families. These boards serve as environmental cues that signal acceptance and help students anticipate positive social interactions, further promoting a sense of belonging in the classroom.

Updating teacher training

At the immediate contextual level, educators play a significant role in addressing social exclusion within the educational environment. For instance, a meta-analysis examining the effectiveness of school bullying intervention programmes globally identifies teacher involvement as a key intervention component of these programmes (Gaffney et al., 2019). Many of these initiatives prepare educators to implement detailed anti-bullying curricula tailored to specific intervention programmes (Gaffney et al., 2019). These programmes primarily train teachers to address issues at the observable level and often adopt a reactive approach. For example, teachers receive training to apply either the "confronting approach" or the "no blame approach" when dealing with incidents of bullying (Gaffney et al., 2019, p. 26). Furthermore, a recent systematic literature review on teacher training for preventing and managing school bullying reports that while teachers often participate in these empirical studies, teacher training in bullying has yet to be examined as a standalone subject; consequently, there is a lack of rigorous evaluation of the effect of training on teachers (Panosso et al., 2023). These authors also highlight the need to update teacher training programmes to help teachers effectively intervene in bullying (Panosso et al., 2023). Moreover, research indicates that educators lacking training in the identification of covert bullying are often less likely to recognise it, may perceive it as less severe, and frequently display diminished empathy towards affected children (Cross et al., 2009). Consequently, these educators are less inclined to intervene, and students may be hesitant to disclose their experiences, feeling that covert bullying will not be taken seriously.

As previously discussed, our conceptual framework on social exclusion advocates for a holistic approach that emphasises the embodied predictive brain, which is socially and culturally embedded. This framework transitions from the traditional 'sense-think-act' model to a 'predictive' approach. However, this advanced understanding is not suitably reflected in present teacher training with regard to social exclusion intervention. Therefore, it is essential to update teacher training programmes with recent research in order to (1) enhance educators' awareness of the neural mechanisms of harm caused by social exclusion and (2) equip them with effective intervention strategies. Above all, this should capture their attention regarding the brain's predictive mechanisms and help them understand the substantial influence of social prediction on the emotional experiences of victims undergoing social exclusion.

Expanding learning areas conducive to children's holistic development

A comprehensive and proactive intervention programme should harness the power of imagination to help children develop alternative and healthy internal models of their social world. This will enable them to make adaptive predictions in their real-life social interactions. Rather than solely focusing on bullying and social exclusion, such programmes should be integrated into a broader range of school environments and diverse areas within the curriculum. For instance, learning experiences in key curriculum areas such as Art and PDHPE can offer opportunities to develop alternative understandings of the social world and the awareness of the interrelationship between the embodied brain and their own well-being. The Australian Curriculum, Assessment and Reporting Authority (ACARA) (2025) articulates in their rationale statement for arts: "The arts engage our senses and give us ways to imagine, celebrate, communicate and challenge ways of knowing, being, doing, and becoming" and "participating in quality arts experiences and practices enriches our social and emotional wellbeing". In art classes, students can be encouraged to explore or simulate various possible scenarios using their imagination and communicate their thoughts and emotions through different modes of expression, such as visual, auditory, and bodily. These imaginative experiences still activate many of the same neural networks that would become active if the students were actually experiencing the scenario in real life (Agnati et al., 2013), which in turn will influence students' predictions when they face a similar scenario in future. In relation to PDHPE, the NSW Education Standards Authority (NESA) (2018) argues that PDHPE supports students to "develop a commitment to the qualities and characteristics that promote and develop empathy, resilience, respectful relationships, inclusivity and social justice" (p.10). To achieve these socio-emotional development goals, in PDHPE classes, students can be provided with more opportunities to deepen their understanding of how embodied brains function in social contexts. However, the scientific approach to socio-emotional development lessons is not yet accessible to students, which is critically related to the lack of teacher training. Furthermore, considering the potential of these subjects, the existing allocation of instructional time dedicated to these subjects, which constitutes only approximately 6-10% of the teaching week, is unequivocally insufficient.

The implications suggested above exemplify numerous potential applications of the findings derived from this school-based neuroscience project and our newly developed conceptual framework on social exclusion in educational practice and social exclusion interventions within the school context. Nevertheless, it is duly acknowledged that further research is needed, particularly replication studies that engage larger and more diverse samples, as well as additional validation of our conceptual framework concerning social exclusion.

Chapter 6 Conclusion

6.1 Main purpose of the study

The overall purpose of this thesis was to elucidate the phenomenon of social exclusion in school-aged children. More specifically, as outlined in Chapter 1, this study had three main objectives, namely: 1) provide a critical analysis of both traditional and contemporary research surrounding social exclusion, with special reference to recent advancements in neuroscience related to emotion and emotional development and the embodied and physically, socially, and culturally embedded, predictive brain; 2) clarify the neural dynamics that underlie the anticipation of social feedback and subsequent feedback appraisal, and investigate the correlations between neurophysiological and self-reported measures associated with social exclusion, and; 3) investigate the implications of this empirical research for identifying effective intervention strategies in response to social exclusion in primary school.

In pursuing these three objectives, this study undertook a critical evaluation of both traditional and contemporary research surrounding social exclusion, incorporating recent advancements in neuroscience and the contemporary theorisation of emotions and emotional development, particularly concerning the embodied, socially, and culturally embedded predictive brain. To capture these critical aspects involved in children's experience of social exclusion, the design of this study included the collection of EEG data, and it was triangulated with other types of data yielded from conventional educational research methods. This 'multi-modal approach' probed both the conscious and subconscious effects of social exclusion by unfamiliar peers, contributing to bridging a significant gap in the existing literature, which currently exhibits a dearth of insights into the conscious repercussions and largely overlooks the subconscious impacts of social exclusion on students' well-being and sense of belonging. Additionally, this research holds the potential to offer valuable insights aimed at mitigating the practice of social exclusion in Australian primary schools and beyond.

6.2 Process of the study

The central premise of this thesis posits that all mental experiences, including emotions, emerge from the embodied, socially and culturally embedded predictive brain. This claim arises from significant advancements over decades in affective neuroscience (Barrett, 2017;2018; Damasio,2006;2012;2018; Immordino-Yang & Damasio, 2007), dynamic systems theory (Thelen & Smith, 1994), and Edelman's (1987) TNGS, alongside the principles of the Bayesian predictive brain (Friston, 2012; Clark, 2016). Building upon these insights and a critical examination of Immordino-Yang and Gotlieb's (2017) biopsychosocial framework of affective processing, we developed a revised and enriched framework on social exclusion equipped with more nuanced descriptions of 'here-and-now' affective processes as experienced by individuals situated in specific contexts. This enriched framework integrates key concepts from the 'predictive brain' theory, especially the Prediction-Feedback dynamics (Kim & Sankey, 2022), to elucidate how the brain's anticipatory mechanisms regulate subsequent affective processes in the context of social exclusion. However, from its initial conceptualisation, this study recognised that historical and current thinking on emotion and cognition that informs much of the existing social exclusion theory in psychology and education has been predominantly linear and dichotomous. It is therefore in conflict with insights derived from recent advances in brain science and the science of dynamic, complex systems produced by previously mentioned scholars. In contrast, the current conceptual framework for social exclusion posits the following assumptions:

(1) Humans are intrinsically social creatures with a profound yearning for belongingness; this innate desire is fundamentally an evolutionarily established biological value.

(2) The brain formulates and operates an internal model of the world shaped by prior experiences and tailored to meet allostatic requirements. This internal model is represented by concepts, all of which are imbued with value and enable the brain to predict forthcoming stimuli.

(3) Emotions and social exclusion operate as dynamic systems, adhering to the principles outlined in the DST.

Guided by this innovative conceptual framework regarding social exclusion, which notably emphasises the Prediction-Feedback cycle, a school-based multi-modal study involving thirty Year 2 students from Australia was designed and conducted. This study aimed to unpack the neural dynamics underpinning the anticipation of social exclusion and subsequent feedback appraisals, exploring the correlation between these neural activities and immediate distress resulting from exclusion by unfamiliar peers and the sense of belonging within their educational context. By incorporating the brain's predictive mechanisms as a fundamental component of this innovative conceptual framework, we directed particular focus towards social prediction in our research, thereby expanding the investigation of victims' emotional experiences beyond mere post-hoc responses to include both anticipatory and post-event processes. Furthermore, the integration of both EEG data and self-reported data facilitated the examination of the correlations between 'real-time' social prediction (e.g., participants pressing 'yes' and 'no' keys to indicate social prediction), neural processes involved in both anticipatory and post-feedback appraisals in the context of social exclusion, the subsequent emotional experiences (e.g., the immediate distress experienced following exclusion by unfamiliar peers) and daily sense of belonging at their school.

6.3 Key findings and implications of the study

To the best of my knowledge, this research represents the first EEG study employing the SJP task with children under eight. It investigates both anticipatory and feedback appraisal processes in the context of social exclusion and their associations with immediate distress from social exclusion and daily feelings of belonging at school. This study has produced several significant and original findings that are currently unattainable within existing educational research. This is partly due to the novel conceptual framework developed in this study, which is grounded in and supported by literature regarding dynamic, complex systems and the science of affective, Bayesian predictive processing. Based on the findings articulated in Chapter 5, we derive five key findings from the present study, which are elucidated below.

Conclusion 1. This study corroborates much previous research showing that when being introduced to a group of similar-aged children, children exhibit an emotional desire to be accepted and to feel they belong within the new community. This suggests that social exclusion by peers can impose existential and neurobiological harm to young children.

Conclusion 2. Real-time neural processes significantly correlate with a child's self-reported responses regarding immediate distress from social exclusion, and with their sense of school belonging. A strong sense of belonging to one's own school acts as protective factor, enhancing emotion regulation and reducing distress, when threatened by unknown peer's rejection.

Conclusion 3. A number of insights can be gained from the findings that provide helpful cues in developing effective strategies to assist primary school children in coping with the felt social and emotional consequences of social exclusion. Strategies should encompass recognition that a child's social prediction regarding whether they will be accepted or rejected significantly influences emotional processes in their own brain. In particular, a child's negative social expectations prohibit their sense of school belonging from exerting its protective effect.

Conclusion 4. Methodologically, the findings from this study confirms the merits of multi-modal research design, and the limitations of self-reported data to probe the emotional experiences that young primary school children encounter when confronted with social exclusion in school, particularly its inability to capture the nuanced relationship between children's prediction of whether they will be accepted or rejected and the social distress that follows social exclusion.

These findings presented herein are both significant and novel within educational research. This significance is partially attributable to their association with the innovative conceptual framework of social exclusion. Furthermore, these findings are corroborated by the extant literature regarding dynamic and complex systems, along with recent advancements in emotion theorisation and Bayesian predictive brain. Drawing upon these four distinct conclusions and the novel conceptual framework synthesised for this study (see Section 2.3), this research advocates a holistic and predictive approach to designing intervention programmes that incorporate factors from various levels of social exclusion dynamics, as delineated in our conceptual framework (refer to Section 2.3).

Regarding the design of the intervention approaches to social exclusion, we call for a transition from a ‘reactive’ to a ‘predictive’ approach. It is pivotal for children to learn how their brains make predictions, gaining awareness of their own unhealthy biases and misinformed expectations. By recognising their brain’s predictive natures, they will be better equipped to shape or re-shape their social decision-making. Also, it is crucial for children to learn the importance of the physical body and the embodied brain in constructing their mental experiences, acknowledging homeostatic feelings that encapsulate evolutionarily evolved and individualised values. Emotion and cognition are intrinsically intertwined, emerging from the activities of an embodied brain, whose primary purpose is to satisfy our homeostatic needs with minimal expenditure. Any intervention programme that fails to consider the body and the embodied and predictive brain will be significantly limited in cultivating children’s full awareness of their social and emotional self.

The findings of this study also emphasise the importance of cultivating students’ sense of belonging within the school community as an integral part of interventions and prevention strategies for social exclusion. The study demonstrated that the positive impacts of school belongingness on achievement and wellbeing are replicated beyond the school, especially when experiencing exclusion from other similar-aged children who are not familiar. This highlights the need for further research into practical strategies that can be implemented at schools to foster students’ sense of school belonging. Recognising the inseparable relationship between academic learning and emotional wellbeing in the school environment (Duncan & Sankey, 2019), these strategies should be incorporated into all aspects of the educational practices of the school, rather than being offered as an ad hoc programme.

The implementation of the aforementioned recommendations necessitates concerted efforts from various stakeholders involved in the education sector, including teachers, teacher educators, and curriculum authorities. Teachers play a pivotal role in the design and implementation of programmes focusing on school-belongingness and the prevention of social exclusion. This underscores the necessity for an update to teacher training programmes, ensuring that teachers are fully equipped to fulfil this significant role. It is imperative that pre-service teachers are furnished with a robust, research-based comprehension of children's emotional and social development, encompassing how emotions and social decision making are engendered by our embodied, and socially and culturally embedded predictive brain. Equipped with this updated knowledge, teachers are better positioned to offer optimal support to victims of social exclusion. At the level of the broader curriculum, it is recommended that key learning areas which promote children's holistic development be expanded. This will require careful reflection on current time distribution across different subject areas, such as Arts and PDHPE, as well as a careful analysis of how research-informed knowledge on the development of the emotional and predictive brain can be incorporated into the pedagogy of these areas.

The findings and recommendations of this study are of paramount importance; however, they do not constitute the entirety of the outcomes. A significant contribution of this research is the development of an innovative conceptual framework on social exclusion, integrating complex concepts from affective neuroscience, dynamic system theory, and the predictive Bayesian brain to explore social exclusion within educational contexts. We anticipate this framework will establish a foundation for future investigations into social exclusion in education. The school-based neuroscience research project developed for this thesis is noteworthy for its demonstration of how to align neurobiological and sociocultural levels of analysis in educational research. To the best of our knowledge, the application of ERP experiment in school-based neuroscience research at The University of Sydney is unparalleled in Australia and is also rare on a global scale. By disseminating the results of this empirical study, we aim to encourage further inquiry into school-based neuroscience within the educational sphere.

6.4 Limitations of the study and future research

Notwithstanding its significance and innovation, as previously discussed, it is fully acknowledged that the generalisability of the main findings of this study is inherently constrained by the scale of the research conducted, which involved a sample of 30 Australian Year 2 students from a single independent school in New South Wales. Subsequent research is imperative to enhance and diversify the sample at both national and international levels. Larger samples encompassing a broader age range, alongside various socioeconomic statuses and cultural backgrounds, will prove beneficial in testing and augmenting the generalisability of this study. To attain a deeper understanding of the implications of our research findings, forthcoming studies should further examine the effects of social predictions and the congruence between social predictions and feedback on young children's emotional regulation when faced with social exclusion, as well as investigate gender differences across a more extensive age spectrum. Additionally, the influence of school belongingness, in conjunction with its interaction with social predictions regarding the anticipation of social exclusion, necessitates further inquiry. Finally, the developmental discrepancies between our sample and older children and adults in prediction error detection warrant further investigation to elucidate the neural mechanisms underlying the Prediction-Feedback cycle in the context of social exclusion. As an educator in primary education, I posit that neuroscience research, including the study presented herein, holds substantial promise for advancing our comprehension of young children's social and emotional development, which has significant implications for both educational scholarship and its practical application.

6.5 Final thoughts

Ultimately, it is hoped more researchers within the discipline of Education will start to appreciate there are very tangible benefits in incorporating neuroscience perspectives into their research practices. Ideally, this will include conducting real-world, school-based EEG investigations in multimodal triangulation with conventional methodologies, allowing researchers to probe both the conscious and, importantly, subconscious aspects of thought and action. It is also hoped this thesis has gone some way in demonstrating that this kind of multimodal approach can provide a more comprehensive and nuanced understanding of the emotional lives of children in our care that, in turn, can contribute to providing scientifically-informed, safe and inclusive school environments, wherein all students thrive, feel they belong, and hence realise their full potential.

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Appendices

Appendix A Ethics Documents

A-1 The University of Sydney Human Research Ethics Committee (HREC) approval Project No. 2020/487

THE UNIVERSITY OF SYDNEY

Research Integrity & Ethics Administration
HUMAN RESEARCH ETHICS COMMITTEE

Monday, 12 October 2020

Dr Minkang Kim
Education; Faculty of Arts and Social Sciences
Email: minkang.kim@sydney.edu.au

Dear Minkang,

The University of Sydney Human Research Ethics Committee (HREC) has considered your application.

I am pleased to inform you that after consideration of your response, your project has been approved.

Details of the approval are as follows:

Project No.:	**2020/487**
Project Title:	**Children's Wellbeing and Learning: Coping with the Emotional Dynamics of Social Exclusion in School**
Authorised Personnel:	**Kim Minkang; Li Li; Sawatari Atomu;**
Approval Period:	**12 October 2020 to 12 October 2024**
First Annual Report Due:	**12 October 2021**

Documents Approved:

Date Uploaded	Version Number	Document Name
26/08/2020	Version 1	PIS for Principal clean version
26/08/2020	Version 3	PIS for Children Clean
26/08/2020	Version 2	PIS for Parents clean version
30/05/2020	Version 1	Flyer for recruitment
30/05/2020	Version 1	Invitation letter from the principal
30/05/2020	Version 2	Consent form for school principal
30/05/2020	Version 2	Consent form for parents
30/04/2020	Version 1	Consent form for children
30/04/2020	Version 1	Debriefing statement
30/04/2020	Version 1	Safety Protocol
30/04/2020	Version 1	The Need Threat Scale
30/04/2020	Version 1	The School Belongingness Scale
30/04/2020	Version 1	Interview questions
30/04/2020	Version 1	Parent Guardian Questionnaire

Condition/s of Approval

- Research must be conducted according to the approved proposal.
- An annual progress report must be submitted to the Ethics Office on or before the anniversary of approval and on completion of the project.
- You must report as soon as practicable anything that might warrant review of ethical approval of the project including:
  - Serious or unexpected adverse events (which should be reported within 72 hours).
  - Unforeseen events that might affect continued ethical acceptability of the project.
- Any changes to the proposal must be approved prior to their implementation (except where an amendment is undertaken to eliminate *immediate* risk to participants).
- Personnel working on this project must be sufficiently qualified by education, training and experience for their role, or adequately supervised. Changes to personnel must be reported and approved.

Research Integrity & Ethics Administration
Research Portfolio
Level 3, F23 Administration Building
The University of Sydney
NSW 2006 Australia

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E human.ethics@sydney.edu.au
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ABN 15 211 513 464
CRICOS 00026A

THE UNIVERSITY OF SYDNEY

- Personnel must disclose any actual or potential conflicts of interest, including any financial or other interest or affiliation, as relevant to this project.

- Data and primary materials must be retained and stored in accordance with the relevant legislation and University guidelines.

- Ethics approval is dependent upon ongoing compliance of the research with the *National Statement on Ethical Conduct in Human Research*, the *Australian Code for the Responsible Conduct of Research*, applicable legal requirements, and with University policies, procedures and governance requirements.

- The Ethics Office may conduct audits on approved projects.

- The Chief Investigator has ultimate responsibility for the conduct of the research and is responsible for ensuring all others involved will conduct the research in accordance with the above.

This letter constitutes ethical approval only.

Please contact the Ethics Office should you require further information or clarification.

Sincerely,

[Redaction]

Dr Haryana Dillon
Chair
Human Research Ethics Committee (HREC 3)

The University of Sydney of Sydney HRECs are constituted and operate in accordance with the National Health and Medical Research Council's (NHMRC) National Statement on Ethical Conduct in Human Research (2018) and the NHMRC's Australian Code for the Responsible Conduct of Research (2018)

A-2 Invitation Letter for Parent/Guardian

THE UNIVERSITY OF SYDNEY

Sydney School of Education and Social Work

Development of Social Relationships in Early Primary Years

Dear Parents and Guardians,

You and your child are invited to take part in a study into the "Development of Social Relationships in the Early Primary Years".

In this study, we will investigate children's perceptions of social relationships, by collecting data from questionnaires and guided interviews, plus temporal neurodynamics captured by electroencephalogram (EEG) while the child views and responds to a series of peer photos presented on a computer screen. Parents/guardians will also be asked to complete two short questionnaires. All data collected in this project will be anonymous (participants will be given a number) and confidential.

Who can get involved?
We are looking for typically developing primary students (6 to 8 years of age) and their parents or guardians. Students with any past or present neurological or psychiatric diagnosis (e.g., Autism, ADHD, anxiety and depression etc.) are ineligible for this study.

Where will it happen?
We are asking your child to be present at a designated room in his/her school.

What will my child do?
Your child will be asked i) to complete two questionnaires; ii) to participate in a debriefing interview; and iii) to participate in EEG data collection. EEG is a completely non-invasive and non-hazardous imaging technique that allows us to measure the tiny electrical currents produced by the brain while your child is viewing and responding to peer photos.

What will I do?
You will be asked to fill out a simple questionnaire providing general information about your child's home environment.

If you would be interested in having your child participate in this study, please click the following link or scan the QR code below for further information.

https://redcap.sydney.edu.au/surveys/?s=DKD3YNYWKP

THE UNIVERSITY OF SYDNEY

Sydney School of Education and Social Work

Dear Families,

A research team at the Centre for Research on Learning and Innovation (CRLI), The University of Sydney has invited students in our school and their parents/guardians to participate in the following research study. I have agreed to allow the team to speak with families interested in this study. If you and your child are interested in participating in the study, please contact the research team using the contact details below.

Kind regards,

Principal

Development of Social Relationships in Early Primary Years

You and your child are invited to take part in a study into the "Development of Social Relationships in the Early Primary Years".

In this study, we will investigate children's perceptions of social relationships, by collecting data from questionnaires and guided interviews, plus temporal neurodynamics captured by electroencephalogram (EEG) while the child views and responds to a series of peer photos presented on a computer screen. Parents/guardians will also be asked to complete two short questionnaires. All data collected in this project will be anonymous (participants will be given a number) and confidential.

Who can get involved?

We are looking for typically developing primary students (6 to 8 years of age) and their parents or guardians. Students with any past or present neurological or psychiatric diagnosis (e.g., Autism, ADHD, anxiety and depression etc.) are ineligible for this study.

Where will it happen?
We are asking your child to be present at a designated room in his/her school.

What will my child do?

Your child will be asked i) to complete two questionnaires; ii) to participate in a debriefing interview; and iii) to participate in EEG data collection. EEG is a completely non-invasive and non-hazardous imaging technique that allows us to measure the tiny electrical currents produced by the brain while your child is viewing and responding to peer photos.

What will I do?
You will be asked to fill out a simple questionnaire providing general information about your child's home environment.

A-3 Participants Information Statement for Principals

THE UNIVERSITY OF SYDNEY

Sydney School of Education and Social Work

ABN 15 211 513 464

Dr. Minkang Kim

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Development of Social Relationship in Early Primary Years

PARTICIPANT INFORMATION STATEMENT

(1) What is the study about?

Children (6 to 8 years of age) and their parents/guardians in your school are invited to take part in a research project about the development of social relationships in the early primary years. In this study, we will investigate children's perceptions of social relationships, by collecting data from the questionnaires and guided interviews, plus temporal neurodynamics captured by electroencephalogram (EEG) when the child views and responds to a series of peer photos presented on a computer screen.

(2) Who is running the study?

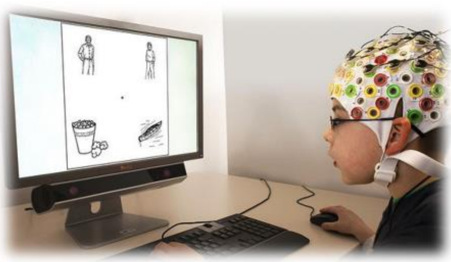
The study is being conducted by Li Li, as part of a Doctor of Philosophy degree at The University of Sydney, under the supervision of Dr Minkang Kim (School of Education and Social Work) and Dr Atomu Sawatari (School of Medical Sciences).

(3) What will the study involve?

We are asking children in your school to be present at a designated room in your school, on a day the child is usually present.

The child will be asked:

1.To participate in EEG data collection (approximately 22 minutes). EEG is a completely non-invasive and non-hazardous imaging technique that allows us to measure the tiny electrical currents produced by the brain. The participating children will wear an EEG cap and then will view and respond to a series of peer photos presented on a computer screen. The electrodes attached to the EEG cap will be connected to a computer that records brain activity while the child views and responds to the photos. To ensure good contact between electrodes and the skin, we will apply a gel. The procedure of cap fitting and electrode



attachment is painless (though it might occasionally give rise to a slight pricking feeling). Children usually find EEG to be fun, but if a child shows any signs of distress he/she will be able to indicate his/her wish to terminate his/her involvement.

After the recording session, children will be provided with the opportunity to wash the EEG gel with towels dampened in lukewarm water. If they wish to wash their hair in a bathroom, a school staff member will take the child to the bathroom equipped with a sink, hypoallergic shampoo, towels and hair dryer.

2.To complete two questionnaires, the first one straight after the EEG experiment and the second one weeks' later after the EEG session.

3.To participate in a debriefing interview straight after the EEG task (approximately 10 minutes). This session will be video-recorded to assist with data analysis.

Parents/guardians will be asked:

1.To fill out a simple questionnaire providing general information about child's home environment.

You, as the principal of the School, will be asked:

1. To send out a flyer that invites the children and parents/guardians to participate in this study. Parents/guardians who are interested in this study will click the link or scan the QR code provided on the flyer to obtain further information about the present study.
2. To provide a venue within the school: If possible, you can provide appropriate space within your school where the research team can collect data. This will allow the children to participate in this study during school hours. The research team will ensure that data collection does not have any influence on the routines of the School.

(4) How much time will the study take?

The EEG session will take approximately 60 to 90 minutes for a child to complete the whole session, which includes completing a questionnaire and a debriefing interview, EEG cap fitting and preparation, and EEG data collection. The second questionnaire will take approximately 10 minutes for a child to complete. The child will complete the second questionnaire two weeks after the EEG session. The participating children will be withdrawn from the classroom for both sessions. The research team will work collaboratively with the participating children's classroom teachers to minimize interruption of their learning. Their classroom teachers will receive a timetable of the sessions and will be asked to choose three preferred time slots. If their first-choice date or time is unavailable, they will be offered one of their next choices.

The estimated length of time for the whole data collection is approximately 6 weeks. With your permission, during this time the researchers will be on site to collect data.

(5) Who can take part in the study?

We are looking for typically developing primary students (6 to 8 years of age) and their parents or guardians. Students with any past or present neurological or psychiatric diagnosis (e.g., Autism, ADHD, anxiety and depression etc.) are ineligible for this study. Therefore, typically developing Stage 1 students in your school will be very suitable for this study.

If parents/guardians wish to communicate with the research team in a language other than English, the research team will provide necessary assistance – we have fluency in Korean and Mandarin, but can accommodate other languages if necessary.

(6) Does our school have to be in the study? Can we withdraw from the study once they've started?

Being in this study is completely voluntary and your school does not have to take part. Your decision whether to participate will not affect your current or future relationship with the researchers or anyone else at The University of Sydney.

If you decide that students in your school can take part in this study and then change your mind, you are free to withdraw at any time, simply by informing the researchers.

(7) Are there any risks or costs associated with being in the study?

There is no foreseeable risks or costs associated with the study. One of the researchers is a fully qualified teacher, who will be working closely with children to ensure developmentally appropriate implementation of the research. There are no known or foreseeable risks or side effects associated with conventional EEG recordings. To avoid child's discomfort and anxiety in the EEG session, we will ensure the research process is child-friendly. For instance, a familiar adult (e.g., a parent or school staff) will be present during the experiment to make the child feel safe.

The research team will ensure that data collection at your school does not have any influence on the routines of the School.

(8) Are there any benefits associated with being in the study?

By participating in this study, children and their parents/guardians will be given opportunities to reflect on interpersonal relationships that children can encounter in their environment. Debriefing at the end of the data collection period will assist this reflection process. If you wish, we will share the findings and potential implementations in the classroom with the teachers by providing a staff development session. Also, if parents/guardians wish, they will receive a summary of the findings and important implications as soon as they are ready.

EEG experiments are tests without any diagnostic value or health benefit. Should an abnormality exist in a child's brain (although this is highly unlikely), this would not be seen in the data acquired in the context of the experiment.

To express our appreciation of each child's contribution, we will provide a Certificate of Participation.

You may also receive feedback in the form of a summary report of the findings, which can be valuable to inform and guide the school's educational practice in the future. This report will be given to your school with notification in advance. If you wish to disseminate any information about this study (on School's newsletter for example), the researchers can provide full support.

(9) What will happen to information that is collected during the study?

By providing your consent, you are agreeing to us collecting personal information about the parents and children for the purposes of this research study. Personal information will only be used for the purposes outlined in this Participant Information Statement, unless you consent otherwise.

Information will be stored securely and your school's identity/information will be kept strictly confidential, except as required by law. Study findings may be published, but your school will not be individually identifiable in these publications. All aspects of the study, including information about your participation, will be strictly confidential and only the researchers listed above will have access to the information.

All data will be stored electronically in a secure network drive provided by the University of Sydney. Hard copy materials will be stored in a locked cabinet in the office of Dr Minkang Kim. Only the approved researchers of this project will have access to the data.

The results of this study may be published in academic journals or used for teaching purposes. The results may also be presented at academic meetings or in talks at academic institutions. Any personal information or identifiable details will not be included in the publication, and pseudonyms will be used. Still images and short extracts of video recordings shall be presented for seminars, conferences and teaching purposes. However, these extracts will be carefully edited (e.g. covering identifying badges/logos, using photo-effects or line drawings) to mask participants' and your school's identities.

(10) Can I tell other people about the study?

Yes, you are welcome to tell other people about the study.

(11) What if I require further information about the study or my involvement in it?

When you have read this information, Dr Minkang Kim and Ms Li Li will be available to discuss it with you further and answer any questions you may have. If you would like to know more at any stage during the study, please feel free to contact either researcher. Dr Minkang Kim is available on minkang.kim@sydney.edu.au or 02 9351 6627. Ms Li Li is available on [redacted].

(12) Will I be told the results of the study?

You have a right to receive feedback about the overall results of this study. You can tell us that you wish to receive feedback by ticking the relevant box on the consent form. This feedback will be in the form of a one-page summary. You will receive this feedback after the study has finished.

(13) What if students indicate that they are at risk of physical or psychological harm on the survey?

Should students indicate on the survey that they are at risk of physical or psychological harm, students will be directed to speak to your school counsellor, and any other duty of care procedures in place at your school will be followed.

(14) What if I have a complaint or any concerns?

Research involving humans in Australia is reviewed by an independent group of people called a Human Research Ethics Committee (HREC). The ethical aspects of this study have been approved by the HREC of the University of Sydney. As part of this process, we have agreed to carry out the study according to the National Statement on Ethical Conduct in Human Research (2007). This statement has been developed to protect people who agree to take part in research studies.

If you (or child in your school) are concerned about the way this study is being conducted or wish to make a complaint to someone independent from the study, please contact the university using the details outlined below. Please quote the study title and protocol number.

The Manager, Ethics Administration, University of Sydney:

- **Telephone:** +61 2 8627 8176
- **Email:** ro.humanethics@sydney.edu.au
- **Fax:** +61 2 8627 8177 (Facsimile)

This information sheet is for you to keep

A-4 Participant Information Statement for Parents

THE UNIVERSITY OF SYDNEY

Sydney School of Education and Social Work

ABN 15 211 513 464

Dr. Minkang Kim

Room 506, Education Building A35
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Web: http://www.sydney.edu.au/

Development of Social Relationships in Early Primary Years

You and your child are invited to take part in a research project. This document contains important information about the project and the roles of potential participants (you and your child). Although your child may not fully understand the details of this project, the researchers strongly suggest that parents/guardians sit down and discuss what is involved. Please ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

PARENTAL INFORMATION STATEMENT

(1) What is the study about?

In this study, we will investigate children's perceptions of social relationships, by collecting data from the questionnaires and guided interviews, plus temporal neurodynamics captured by electroencephalogram (EEG) while the child views and responds to a series of peer photos presented on a computer screen.

(2) Who is running the study?

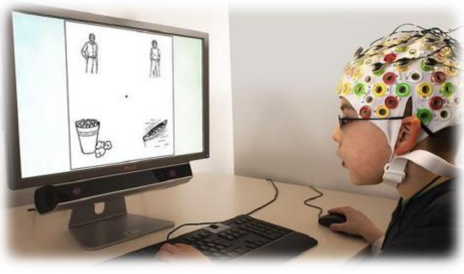
The study is being conducted by Li Li, as part of a Doctor of Philosophy degree at The University of Sydney, under the supervision of Dr Minkang Kim (School of Education and Social Work) and Dr Atomu Sawatari (School of Medical Sciences).

(3) What are we asking your child and you to do?

The study will be conducted at your child's school.

The child will be asked:

1.To participate in EEG data collection (approximately 22 minutes). EEG is a completely non-invasive and non-hazardous imaging technique that allows us to measure the tiny electrical currents produced by the brain. The participating children will wear an EEG cap and then will view and respond to a series of peer photos presented on a computer screen. The electrodes attached to the EEG cap will be connected to a computer that records brain activity while the child views and responds to the photos. To ensure good contact between electrodes and the skin, we will apply



a gel. The procedure of cap fitting and electrode attachment is painless (though it might occasionally give rise to a slight pricking feeling). Children usually find EEG to be fun, but if a child shows any signs of distress he/she will be able to indicate his/her wish to terminate his/her involvement.

After the recording session, children will be provided with the opportunity to wash the EEG gel with towels dampened in lukewarm water. If they wish to wash their hair in a bathroom, a school staff member will take the child to the bathroom equipped with a sink, hypoallergic shampoo, towels and hair dryer.

2.To complete two questionnaires, the first one straight after the EEG experiment and the second one two weeks later after the EEG session.

3.To participate in a debriefing interview straight after the EEG task (approximately 10 minutes). This session will be video-recorded to assist with data analysis.

Parents/guardians will be asked:

1.To fill out a simple questionnaire providing general information about child's home environment.

(4) How much time will the study take?

For you:

It will take approximately 10 minutes for you to complete the questionnaire online.

For your child:

The EEG session will take approximately 60 to 90 minutes for a child to complete the whole session, which includes completing a questionnaire and a debriefing interview, EEG cap fitting and preparation, and EEG data collection. The second questionnaire will take approximately 10 minutes for your child to complete. Your child will complete the second questionnaire two weeks after the EEG session. Your child will be withdrawn from the classroom for both sessions. The research team will work collaboratively with your child's classroom teacher to minimize the interruption of his/her learning. Their classroom teachers will receive a timetable of the sessions and will be asked to choose three preferred time slots. If their first-choice date or time is unavailable, they will be offered one of their next choices.

(5) Who can take part in the study?

We are looking for typically developing primary students (6 to 8 years of age) and their parents or guardians. Students with any past or present neurological or psychiatric diagnosis (e.g., Autism, ADHD, anxiety and depression) are ineligible for this study.

(6) Can we withdraw from the study?

Participation in this study is completely voluntary and you and your children are free to withdraw from the project at any time. Your decision to withdraw will not affect your current or future relationship with your school, or the researchers or anyone else at The University of Sydney.

(7) Are there any risks or costs associated with being in the study?

There are no foreseeable risks or costs associated with the study. One of the researchers is a fully qualified teacher, who will be working closely with your child to ensure developmentally appropriate implementation of the research. There are no known or foreseeable risks or side effects associated with conventional EEG recordings. To avoid your child's discomfort and anxiety in the EEG session, we will ensure the research process is child-friendly. For instance, a familiar adult (e.g., a parent or school staff) will be present during the experiment to make the child feel safe.

If your child experiences feelings of distress because of their participation in this study, you can contact a member of the research team (their details are listed below). If your child experiences distress while completing the experiment or the survey, they will be directed to see the school counsellor or another appropriate member of school staff.

If your child discloses at-risk experiences or distress, they will be advised to speak to a parent/guardian, and will be provided with information referring them to the school counsellor and she will follow their usual duty of care procedure.

(8) Are there any benefits associated with being in the study?

By participating in this study, you and your child will be given opportunities to reflect on interpersonal relationships that children can encounter in their environment. Debriefing at the end of the data collection period will assist this reflection process. Also, if you opt, you will receive a summary of the findings and important implications, when they are ready.

EEG experiments are tests without any diagnostic value or health benefit. Should an abnormality exist in your child's brain (although this is highly unlikely), this would not be seen in the data acquired in the context of the experiment.

To express our appreciation of your and child's contribution, we will provide a Certificate of Participation. The Certificate will contain a picture of your child taken when participating in the study. If your child does not want his/her photo taken, he/she will still receive the Certificate.

(9) What will happen to the information that is collected during the study?

All data collected in this study will be kept strictly confidential, except as required by law. All data will be stored electronically in a secure network drive provided by the University of Sydney. Hard copy materials will be stored in a locked cabinet in the office of Dr Minkang Kim. Only the approved researchers of this project will have access to the data.

The results of this study may be published in academic journals or used for teaching purposes. The results may also be presented at academic meetings or in talks at academic institutions. Results will always be presented in such a way that data from individual volunteers cannot be identified.

(10) Can I or my child tell other people about the study?

Yes, you are welcome to tell other people about the study.

(11) Can I be present during the EEG experiment?

Yes, you are welcome to accompany your child during the data collection.

(12) What if I require further information about the study or my involvement in it?

When you have read this information, Dr Minkang Kim and Ms Li Li will be available to discuss it with you further and answer any questions you may have. If you or your child would like to know more at any stage during the study, please feel free to contact either researcher. Dr Minkang Kim is available on minkang.kim@sydney.edu.au or 02 9351 6627. Ms Li Li is available on [Redaction].

(13) Will I be told the results of the study?

You and your child have a right to receive feedback about the overall results of this study. You can tell us that you wish to receive feedback by ticking the relevant box on the consent form. This feedback will be in the form of a one-page summary. You will receive this feedback after the study has finished.

THE UNIVERSITY OF SYDNEY

(14) What if I have a complaint or any concerns?

Research involving humans in Australia is reviewed by an independent group of people called a Human Research Ethics Committee (HREC). The ethical aspects of this study have been approved by the HREC of the University of Sydney. As part of this process, we have agreed to carry out the study according to the National Statement on Ethical Conduct in Human Research (2007). This statement has been developed to protect people who agree to take part in research studies.

If you (or your child) are concerned about the way this study is being conducted or wish to make a complaint to someone independent from the study, please contact the university using the details outlined below. Please quote the study title and protocol number.

The Manager, Ethics Administration, University of Sydney:

- **Telephone:** +61 2 8627 8176
- **Email:** ro.humanethics@sydney.edu.au
- **Fax:** +61 2 8627 8177 (Facsimile)

This information sheet is for you to keep

A-5 Participant Information Statement for Children

THE UNIVERSITY OF SYDNEY

Sydney School of Education and Social Work

ABN 15 211 513 464

Dr. Minkang Kim

Room 506, Education Building A35
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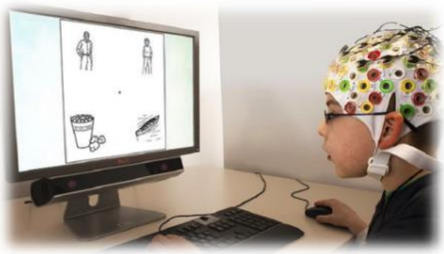
Email: minkang.kim@sydney.edu.au
Web: http://www.sydney.edu.au/

Development of Social Relationships in Early Primary Years

You are invited to take part in a research project. This letter has important information about the project and the tasks you need to complete. Please ask your parents if you have any questions. Take time to decide whether or not you wish to take part. Thank you for reading this.

PARTICIPANT INFORMATION STATEMENT FOR CHILDREN



(1) What is the study about?
In this study, we are going to observe how your brain works while you respond to photos of other children on a computer screen.

(2) Who is running the study?
A research team from the University of Sydney will visit your school and carry out the study at your school.

(3) What are we asking you to do?
You are going to wear a cool EEG cap during the experiment. This cap will collect information from your brain and send it to a computer. While putting on the cap, we will apply a gel to make sure you feel comfortable wearing the cap. You might experience a prickly feeling but you will not be hurt by wearing the EEG cap.

After that, we will video you chatting with the researcher so we can remember what you said. You will also answer a few questions on an iPad.

The researcher will visit your school again and ask you to answer a few more questions on an iPad later.

(4) Can my parents or teacher come with me?
Yes, you parents can come to the study with you. If your parents can not come, one teacher from your school will be with you.

(5) Can you ask to stop anytime you want?
Yes, you can ask to stop at any time.

(6) Will I receive a Certificate for Participation?
Yes, at the end of the experiment, you will receive a certificate with your photo on it. If you don't want to take a photo, you can have a certificate without the photo.

A-6 Principal, Parent/Guardian, and Child Consent Form

THE UNIVERSITY OF SYDNEY

Sydney School of Education and Social Work

ABN 15 211 513 464

Dr Minkang Kim

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Development of Social Relationship in Early Primary Years

PRINCIPAL CONSENT FORM

I, ... [PRINT NAME of PRINCIPAL],

give consent for the research to be undertaken with children and their parents/guardians at

.... [PRINT NAME of SCHOOL].

In giving my consent I acknowledge that:

1. The purpose of the study, procedures required for the project, the time, any risks/benefits involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

2. I have read the Participant Information Statement and have been given the opportunity to discuss the information and the school's involvement in the project with the researcher(s).

3. I understand that members of my school community's involvement in this study is completely voluntary – I am not under any obligation to consent.

4. I understand that students and families in my school can withdraw from the study at any time, without affecting my relationship with the researcher(s) or the University of Sydney now or in the future.

5. I understand that personal information about the child and parent/guardian, who have

given their consent to participate in the study, will be stored securely and will only be used for the purpose of interpretation and analysis as part of this project.

6. I understand that the results of this study may be published, and that publications will not contain school's name or any identifiable information about me, children enrolled in the school and their parents/guardians.

7. I understand short extracts of collected data shall be presented at academic conferences. However, these extracts will be carefully edited to mask participants' identities. Also, data will not be shared with anyone other than the approved researchers.

8. I consent to:

- Send out flyers to the families whose children are enrolled in the school
- Children's data being collected at the school
- Provide a suitable venue for EEG and interview data collection at the school

Would you like to be contacted for future studies YES ☐ NO ☐

Would you like to receive feedback about the overall results of this study?

YES ☐ NO ☐

If you answered YES, please indicate your preferred form of feedback and address:

☐ Postal: ____

____

☐ Email: ____

....

Signature of Principal

....

PRINT name of Principal

....

Date

THE UNIVERSITY OF SYDNEY

Sydney School of Education and Social Work

ABN 15 211 513 464

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Development of Social Relationship in Early Primary Years

PARTICIPANT CONSENT FORM

I, ... [PRINT NAME of PARENT/GUARDIAN], being over the age of 18 years, hereby consent to my child participating in this study. I affirm my child, ... [PRINT NAME of CHILD] expressed her/his agreement. rdx

In giving my consent I acknowledge that:

1. The purpose of the study, procedures required for the project, the time, any risks/benefits involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

2. I have read the Participant Information Statement and have been given the opportunity to discuss the information and my child's and my involvement in the project with the researcher/s.

3. I understand that participation in this study is completely voluntary – my child and I are not under any obligation to consent.

4. I understand that:

- My child is free to withdraw from the project at any time and is free to decline to answer particular questions.
- While the information gained in this study will be published as explained in the

Participant Information Statement, my child will not be identified, and individual information will remain confidential.

- My child may ask that the recording/observation be stopped at any time, and he/she may withdraw at any time from the session without disadvantage. My child's withdrawal will not affect his/her relationship with the researcher(s) or the University of Sydney now or in the future.

- The study is not a diagnostic and would have no potential for detecting an abnormality in my child's brain, should this abnormality exist.

5. I understand that:

- I am free to withdraw myself and my child from the project at any time and am free to decline to answer particular questions.

- While the information gained in this study will be published as explained, neither I nor my child will not be identified, and individual information will remain confidential.

- My child and I may withdraw at any time from the session without disadvantage. My withdrawal will not affect my relationship with the researcher(s) or the University of Sydney now or in the future.

- The study is not a diagnostic and would have no potential for detecting an abnormality in my capacity, should this abnormality exist.

6. I understand short extracts of collected data shall be presented at academic conferences. However, these extracts will be carefully edited to mask participants' identities. Also, data will not be shared with anyone other than the approved researchers.

I consent to:

- Completing a questionnaire about my child's family background
- EEG recording of my child
- Video recording of my child
- Photo taking of my child
- Presenting collected data at academic meetings

The research team will send you information related to the present study via email, so it is essential for us to have your email. Please provide your email.

☐ Email: ____

Would you like to receive feedback about the overall results of this study?

YES ☐ NO ☐

If you answered YES, please indicate your preferred form of feedback and address:

☐ Postal: ____

____

☐ Email: ____

Would you like to receive information on other research participation opportunities via the address provided above? YES ☐ NO ☐

………………………………………………………….
Signature of Parent/Guardian

………………………………………………………….
PRINT name of Parent/Guardian

………………………………………………………….
Date

THE UNIVERSITY OF SYDNEY

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Development of Social Relationship in Early Primary Years

PARTICIPANT CONSENT FORM

I, ... [PRINT NAME of CHILD], agree to take part in this study and agree to take part in:

- EEG recording
- Video recording
- Photo taking

I have read the Participant Information Statement. My parents have explained the study to me. I know what the study is about and the part I will be involved in. I know that I do not have to answer all of the questions and that I can decide not to continue at any time.

………………………………………………………..
Signature of Child

……………………………………………………….
PRINT name of Child

……………………………………………………….
Date

A-7 Debriefing Statement

THE UNIVERSITY OF SYDNEY

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Development of Social Relationship in Early Primary Years

Thank you for participating in this study. In order to gather the information we were looking for, we withheld some information about some aspects of this study. Now that the experiment is over, we will describe the main aim of the EEG experiment, of course, we will also answer any of your questions and we will provide you with the opportunity to decide whether you would like to have your data included in this study.

DEBRIEFING STATEMENT

(1) What was the main aim of the study?

As explained, this project is about the development of social relationship in the early primary years. We are investigating children's emotional responses in social exclusion contexts. The main aim of the EEG experiment was to investigate how children felt when they were rejected by peers to join in an online game team.

(2) Taking part is voluntary

Although you have already completed the tasks, your involvement is still voluntary, and you and your children may choose to withdraw the data you provided prior to receiving this debriefing advice. Your decision to withdraw will not affect your current or future relationship with your school, or the researchers or anyone else at The University of Sydney.

(3) What will happen to information that is collected during the study?

If you agree to allow us to use your data, you can be assured that all data collected in this study will be kept strictly confidential (except in the exceptional case that it is required by law). All data will be stored electronically in a secure network drive provided by the University of Sydney. Hard copy materials will be stored in a locked cabinet in the office of Dr Minkang Kim. Only the approved researchers of this project will have access to the data.

The results of this study may be published in academic journals or used for teaching purposes. The results may also be presented at academic meetings or in talks at academic institutions. Results will always be presented in such a way that data from individual volunteers cannot be identified.

(4) What if I require further information about my involvement in it?

If you have questions later, Dr Minkang Kim and Ms Li Li will be available to discuss it with you further

A-8 Safety Protocol

Sydney School of Education and Social Work

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Safety Protocol: Children's Wellbeing and Learning: Coping with the Emotional Dynamics of Social Exclusion in School

- Approved members of the research team (Ms Li Li, Dr Minkang Kim) will meet participants (6-8 years old children) in a designated room of ____________ School.
- The estimated length of time for the whole data collection is approximately 6 weeks. With the school principal's permission, during this time the researchers will be on site to collect data.
- Two researchers have submitted Working with Children Check Clearance.
- Two researchers will abide by the health and safety policy of ____________ School.
- During research, researchers will carry a mobile phone in the case of an emergency.
- Researchers will dress appropriately for the research context and culture, and will represent the University of Sydney.
- Additionally, safety during data collection will be ensured by:
    - EEG data collection will usually occur between 8 am and 1pm.
    - Running a 'pilot' before the main data collection to ensure that the data collection procedure is properly tailored to children and engages them in a positive experience.
    - Permitting parents/teachers to be present at the EEG data collection site in

order to make the research process child-friendly.

  - Ensuring that data collection has minimal influence on children's normal classroom engagement.
  - Ensuring that data collection does not have any influence on the staff's duties and routines of the School.

- This safety protocol has been agreed and accepted by two internal investigators.

Chief Investigator: Dr. Minkang Kim

Co Investigator: Ms. Li Li

Appendix B Questionnaires

B-1 Parents Guardians Questionnaires

Appendix 1 Parents Guardians Questionnaires

Participant # ________________________ **Date ______________________**

READ THIS FIRST: These questionnaires are to be filled out by the parent(s) or guardian(s). For all of the questions in the survey, your answers are kept private, and won't be used in a way that identifies you or your child. If you feel uncomfortable answering any of the items, feel free to ignore them. If you have questions, don't hesitate to ask us.

Who is completing this survey? (check one)
- O Mother (including biological, adoptive and stepparent)
- O Father (including biological, adoptive and stepparent)
- O Other – please specify: ________________

Are you this child's primary caregiver?
O Yes
O No

What is your gender?
O Male O Female O Other

Child's Date of Birth (MM /YY): ___/___/___

Child's Gender:
O Male O Female O Other

Child's birth order: This child is ______ out of _____ total children

Please list the gender and age(s) of your child's sibling(s).
Example: Ages of brothers: 10, 4
Age(s) of brother(s): ________________
Age(s) of sister(s): ________________

Country of your birth:
O Australia
O Other – please specify: ________________
Are you of Aboriginal or Torres Strait Islander origin?
O No
O Yes, Aboriginal
O Yes, Torres Strait Islander

Who does your child currently live with? (ex., biological parents, adoptive parents, stepparents, other family members)
____
For how many days of the week? _______

Language(s) currently spoken at home:
Primary: _______________________
Other: _________________________

Religion(s) practiced in the home:

____

Parent 1: ○ Mother ○ Father ○ Other

Highest level of education **parent 1 has completed:**

○ Postgraduate Degree
○ Bachelor Degree
○ Certificate
○ Junior Secondary Education
○ Graduate Diploma and Graduate Certificate
○ Advanced Diploma and Diploma
○ Senior Secondary Education
○ Primary Education

Parent 2: ○ Mother ○ Father ○ Other

Highest level of education parent 2 has completed:

○ Postgraduate Degree
○ Bachelor Degree
○ Certificate
○ Junior Secondary Education
○ Graduate Diploma and Graduate Certificate
○ Advanced Diploma and Diploma
○ Senior Secondary Education
○ Primary Education

Total family income last year:

○ Less than $25,000
○ $25,000 - $49,999
○ $50,000 - $74,999
○ $75,000 - $99,999
○ $100,000 - $124,999
○ $125,000 - $149,999
○ $150,000 - $174,999
○ $175,000 - $199,999
○ $200,000 or more
○ Prefer not to answer

B-2 Need Threat Scale (NTS)

The Need Threat Scale

Item #	Items
1	I felt unsure of myself
2	I felt invisible
3	I felt I didn't fit in with the others
4	I felt like an outsider
5	I felt rejected
6	I felt I did not matter
7	I felt I did not exist
8	I felt I was unable to influence the action of others
9	I felt powerful
10	I felt important
11	I felt I belonged to the group
12	I felt proud and confident
13	I felt liked
14	I felt happy with how things are
15	I felt useful
16	I felt I had the ability to change the panel member's decision
17	I felt good about myself

Note. Items were measured on a 5-point Likert Scale from 1 = "Not at all" to 5 = "Extremely". Items 9-17 were reverse coded. Higher scores indicated more ostracism.

B-3 Interview Questions

The prompt questions for the debrief session

Categories	Questions
embodied distress and discomfort	How did your body feel when you saw the ‘NO’ feedback on the screen?
embodied emotions	How did you feel when you saw the ‘NO’ feedback on the screen?
feelings and thoughts evoked	What were you thinking when you saw the ‘NO’ feedback on the screen?

B-4 School Belongingness Scale (SBS)

The School Belongingness Scale

		Almost never	Sometimes	Often	Almost Always
1	I can really be myself in this school.	1	2	3	4
2	I feel like I don't belong to this school.	1	2	3	4
3	I like my teachers and friends. They are close to me.	1	2	3	4
4	I think that I am not included in most of the activities at school.	1	2	3	4
5	I feel that I am accepted by other people at school.	1	2	3	4
6	I feel myself excluded in this school.	1	2	3	4
7	I see myself as a part of this school.	1	2	3	4
8	In this school, my friends and teachers usually ignore me.	1	2	3	4
9	I think that people care about me in this school.	1	2	3	4
10	I have no close relationship with people in this school.	1	2	3	4

Scoring and Interpretation Guide

- Create the School Belongingness Scale score by summing all 10 items.
- Five (exclusion subscale items) reverse-scoring necessary.
- Scales
  - Social Exclusion Scale: Items 2,4,6,8, and 10.
  - Social Acceptance Scale: Items 1,3,5,7, and 9.
- Higher scale scores represent greater levels of school belonging.