# ETHICAL IMPLICATIONS OF EMERGING MIXED REALITY TECHNOLOGIES

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# CONTENTS

ABSTRACT 2

NOTES ON AUTHORS 3

ACKNOWLEDGEMENTS 4

INTRODUCTION 5
- Definitions 5

ETHICAL FRAMEWORKS FOR VR AND AR 7

EXPECTATIONS OF PRIVACY IN PUBLIC SPACE 8

ACCESSIBILITY, INCLUSIVITY AND EXCLUSION 12

SURVEILLANCE AND PLATFORM POWER 17

THE MILITARY-ENTERTAINMENT COMPLEX 21

EMPATHY 25

WORK 27

APPENDIX 30
- Methodology 30

REFERENCES 31

# ABSTRACT

Virtual and Augmented Reality technologies are increasingly finding foothold in culture and society. As these technologies stake out an increasingly large space in areas like entertainment, work, health and communication, it is important that we are equipped to think lucidly about both their benefits and their drawbacks. This document presents a thematic review of the literature that focuses on the 'ethics' or ethical implications of virtual, augmented and mixed reality technologies. We cover both the perceived benefits to individuals and society, as well as associated risks and ambiguities. We survey research published in fields such as media studies, Human-Computer Interaction, philosophy of technology, and surveillance studies, as well as work published in the popular media. We outline areas pertaining to the ethics of AR and VR, broadly encompassed in the following categories: 1) ethical frameworks for VR and AR, 2) expectations of privacy in public space, 3) accessibility, inclusivity and exclusion, 3) surveillance and platform power, 4) the military entertainment complex, 5) empathy, and 6) work.

**Keywords:** Virtual Reality, VR, Augmented Reality, AR, Mixed Reality, Ethics, digital platforms, work, privacy, surveillance, law, disability, labour.

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# INTRODUCTION

This report presents a thematic review of existing literatures about the 'ethics' of head-mounted virtual reality (VR) and mobile based and wearable augmented reality (AR) technologies. In thinking about the ethics of VR/AR, we are interested in questions of how these technologies affect society, whose interests they serve (and whose get left out), and the value frameworks used in their evaluation and design. The literature surveyed covers a wide range of ethical topics and issues, such as disability, gender, data surveillance and data accumulation, privacy, empathy and work, yet there are some commonalities across disparate topics and literatures. Firstly, the literature generally suggests that a better understanding of these human-value-technology entanglements can substantially contribute to a more responsible design and use of technologies. Second, given that VR and AR (in most, but not all instances) are relatively nascent technologies that are more imagined than used, much of this research is about anticipating the impact of these technologies becoming widely adopted in everyday life. The literature surveyed includes academic literature, but also a range of critical public media/writing. Academic material – from across fields like media studies, Human-Computer Interaction, philosophy of technology, and surveillance studies – predominantly included position papers (based on existing literature and recent case studies), but also qualitative empirical studies.

## DEFINITIONS

The literature we surveyed takes the terms augmented and virtual reality to denote specific kinds of technologies. It is worth noting that some literature conflates virtual reality with other kinds of immersive digital technologies (see Brey 1999), or conflates augmented reality with mixed reality or other kinds of ubiquitous technologies (e.g. 'Internet of Things' technologies, see Wolf et al., 2018). Given our focus here on the recent suite of emerging VR and AR technologies, studies using the term in this way were not included (with the exception of using Wolf et al.'s (2018) more permissive definition of AR to discuss the topic of work, AR and wearables).

Our approach understands VR technology as denoting immersive, completely digital or simulated experiences reliant on encompassing head mounted displays (e.g. Oculus Rift, HTC Vive, PlaystationVR). We follow Markowitz and Bailenson's definition of *immersive* VR systems which "typically include hardware such as a head-mounted display (e.g., a headset that people wear to orient space and sight in the virtual world) and sensory feedback (e.g., auditory, haptic responses) to provide a surrounding experience for the user" (2019, n.p.).

AR encapsulates a wider range of technologies which digitally overlay physical spaces or objects. These technologies include wearable head mounted displays (such as a Microsoft HoloLens device or a Magic Leap headset) or smart glasses (like Google Glass or Vuzix's smartglasses), as well as mobile interfaces (e.g. mobile apps like Snapchat or games like Pokémon Go). However, we believe a crucial distinction between mobile-based AR and mobile devices more broadly is their reliance, or not, on Simultaneous Localization and Mapping (SLAM) technologies – that is, the construction of a digital map of the environment the device is located within (used elsewhere in autonomous tech like drones, robotics and self-driving cars).

While AR and VR are distinct things, there are many common ethical issues. For our purposes here, we consider AR and VR as both on the reality-virtuality continuum (Madary and Metzinger, 2016), where "the real environment is located at one extreme of the continuum and an entirely virtual environment is located at the other extreme" (2016, p.2). Since different VR and AR technologies existing across this spectrum, we argue discussing the ethical concerns and issues of both alongside one another is fruitfull.

# ETHICAL FRAMEWORKS FOR VR AND AR

Reflections upon the ethical use and design of VR and AR, and the development of ethical frameworks and recommendations is common in the literature we surveyed. The broad theme is that a better understanding of human-value-technology entanglements can contribute to the more responsible design and usage of such technologies. The majority of literature reviewed existing VR literature, explicitly addressing ethical issues (or extrapolated the ethical issues out of these papers) and would conclude with an often-speculative anticipatory framework for ethical use and design of VR (see e.g. Kenwright, 2019; Madary and Metzinger, 2016; Spiegel, 2018). Some papers reviewed here had a tendency to play into media-effects (specifically, media panic) style claims about the perceived future impacts of VR, in vein with similar panics presently seen around digital gaming more broadly. Others – such as Madary and Metzinger's (2016) philosophy of technology grounded paper – more rigorously justify a concern for why ethical consideration of VR is necessary, situating claims around philosophical ideas about human plasticity and conditioning through technology. Through thinkers like Heidegger, Madry and Metzinger make the claim that VR may significantly affect us because humans' capacities for thought, action and so on are always and already shaped through encounters with technology.

One central methodological issue with these papers is that they are often too speculative to be of any practical use. Consider the large number of papers we reviewed on the privacy-associated risks associated with public use of Google Glass (Brinkman, 2014; Kostios, 2015; Schwind et al., 2018). While this was envisioned by Google at the time, the Glass never saw widespread public adoption, and now primarily exists in 2020 in the context of factory work (Savov, 2017); an unforeseen outcome in those speculative papers. Perhaps the most useful and perceptive solution to address this issue came from Kudina and Verbeek (2019). Kudina and Verbeek frame a response to developing ethical principles around rapid technological change in light of the Collingridge problem – that is, the problem where if a technology is not yet widely adopted, we run the risk of too speculatively anticipating its impacts. But, if we wait until it is widely adopted in society, it becomes difficult to challenge its entrenchment and power. Offering a potential way out of this double bind, they suggest paying further attention to mediation, and specifically to how individuals come to envision emerging technologies which are imagined and discursively framed by corporations. Kudina and Verbeek suggest that by looking at human practices and experiences we can learn something about how emerging technologies might conflict or fit in within existing value frameworks.

# EXPECTATIONS OF PRIVACY IN PUBLIC SPACE

The way that AR and VR intersect (and often conflict) with expectations of privacy in public space featured as a prominent theme. We found a more varied and sustained engagement with the topic in the AR literature, which – as Mark Pesce notes – "*by virtue of the way they operate, augmented reality systems must simultaneously act as very sophisticated surveillance systems*" (Pesce, 2017).

There was heavy emphasis on privacy in public, with respect to AR specifically, around wearable and head-mounted technology. Many of these accounts were speculative accounts of Google Glass (Brinkman, 2013; Kostios, 2015; Wolf et al., 2018), a brand of smart glasses developed by Google first announced in 2014 but discontinued in 2015 following limited adoption beyond researchers and developers. Others focused on questions of who and what is surveilled, with specific focus on privacy issues for people other than the users of the technology and things in an environment (see de Guzman et al., 2019; Dainow, 2014). Wolf et al. (2018), for instance, encourage us to move away from a consideration of AR as a visual medium in their discussion of privacy. They suggest we instead focus on other forms of information that is captured by AR devices, such as voice and sound that may be present in an environment, which is currently overlooked in legislation and AR privacy discussions.

Other work (Mann, 2013; Mann and Ferenbok, 2013; Denning et al., 2014) touches on the potential for AR to foster an environment where everyone can surveil – terming this 'sousveillance'. Presenting an optimistic outlook, Mann and Ferenbok (2013) suggest that this sousveillance represents a kind of political challenge to hierarchical, top-down surveillance by the powerful, and facilitating a 'surveillance from below' (giving the example of recording the police as an accountability measure. 2013, p.20). The theme of privacy in public spaces with respect to AR was also key in legal perspectives. Wassom (2014) points out gaps in UK based legal regulation around AR – including privacy – and Blodgett-Ford and Supponen (2018) highlight some of the US legal issues present in advertising via AR (and VR), such as in use of biometric and geographic data collection for advertising. Meese (2014) focuses on the legal blind spots in Australian privacy law in regulating widespread AR technologies (noting issues specific to Australia, such as a lack of regulatory or constitutional privacy protections as seen in Europe and the US respectively).

There was also an emphasis on AR, public space and expectations to seclude oneself from others and particular forms of information. Kostios (2015) gives the example of users in public spaces projecting AR images onto private property, also discussed by Blitz (2018) as a form of 'personalisation of space', in the context of US constitutional law. There were also concerns

about AR and the projection of harmful material (see Lemley and Volokh, 2018). Pesce (2017) gives the particularly striking example of AR's weaponization as a tool for public hate speech. He writes:

> "What if that blank canvas gets painted with hate speech? What if, perchance, the homes of 'undesirables' are singled out with graffiti that only bad actors can see? What happens when every gathering place for any oppressed community gets invisibly 'tagged'? In short, what happens when bad actors use Facebook's augmented reality to amplify their own capacity to act badly?" (2017, n.p.).

Robertson (2019) identifies some of these same concerns around the case of Mark AR – a mobile application allowing the creation and placement of persistent digital images in real world environments. She notes that the developers of the application have actively had to incorporate features to minimise the potential for AR's weaponization, such as requiring real names and the need for active human moderation. In contrast, while there is concern around expectations of privacy in public, a number of AR art practitioners have shown the expressive and activist potential of augmented public space. Skwarek, for instance, creates a virtually rendered elimination of the border between Israel and Palestine at the Gaza Strip (see Skwarek, 2018). Others have employed AR for subversive cultural commentary. Katz (2018) discusses the use of AR by artists to overlay artworks at the New York Museum of Modern Art with images or text (making artworks unrecognisable) – the goal of which being to challenge the authority of high art as something often produced by individuals with certain social and class interests. While these examples do not 'lessen' the issues associated with AR as invasive, it does show that this can at least be done for expressive or purposeful ends.

Discussions about the public use of VR – and its intersections with feelings and expectations of privacy – were relatively limited. In an account of the use of VR in art gallery spaces, Parker and Saker (2020) outline the qualitative experience of this increasingly popular 'public' use of VR. Inspired by Henri Lefebvre's account of spatiality, Parker and Saker understand the art museum as both spatial and social – a dynamic that VR-based experiences alters. As they point out, through interviews with gallerygoers, VR created feelings of 'freedom', inasmuch that their view of the virtual space was not visible to others – providing a "mastery of space and autonomy that is rare in a crowded museum" (2020, p.10). Conversely, their participants describe feelings of vulnerability – particularly in being watched using the technology, which we also found in our research into the use of VR videos in the zoo (Carter et al., under review). As scholars like Golding (2019) discuss elsewhere, VR is a medium that is imagined largely around the performance of an embodied spectacle, through the user making a range of bodily gestures corresponding to movements on the screen. Museums – as social, public spaces – are inherently characterised by a dynamic of watching others, something that Parker and Saker's (2020) participants also felt to be intensified through VR, where the user's bodily performance of VR became part of the museum experience. While Parker and Saker do not engage with ethics, what they underline here is the ways 'private' VR in public spaces still presents challenges in the context of existing expectations of privacy in public space.

# CASE STUDY ONE
# THE POLITICS OF SPACE IN POKÉMON GO

Its July 2016, 21 years since the original release of Pokémon Red and Green for the Gameboy, in which players travel the virtual environment to catch virtual creatures called Pokémon. Unlike the Gameboy game, where this encounter with Pokémon takes place in the virtual space resembling the Japanese region of Kantō, players of Pokémon Go wander the streets of the real-world city to 'catch 'em all'. The game uses smartphone-based AR rather than playing the game on the screen of a Game Boy. Players are notified on their phones when they have encountered wild Pokémon. They pick up their phones and move the device around them – using the phone's camera to scan the environment. Eventually, a digital rendition of a Pokémon appears, overlaying the image of the physical environment captured by the camera. Pokémon in this way came to inhabit a wide range of spaces from schools, to supermarkets, to funerals and memorials.

The result was conflict; between physical property laws and the developer Niantic's ability to repurpose existing public and private spaces for augmented play. People found their homes transformed into virtual playgrounds, and many others complained to the police in response to the rapid and unexplained increase in foot traffic in parks and other public spaces (YeeFen Lim, 2020). Private businesses quickly sought the ability to remove, or host, Gyms or Pokéstops to capture this attention, and in 2019, Niantic settled a lawsuit brought by US homeowners that in response to this issue – what rights do technology companies have to dictate digital layers over existing physical spaces that already have established legal, cultural and social norms?

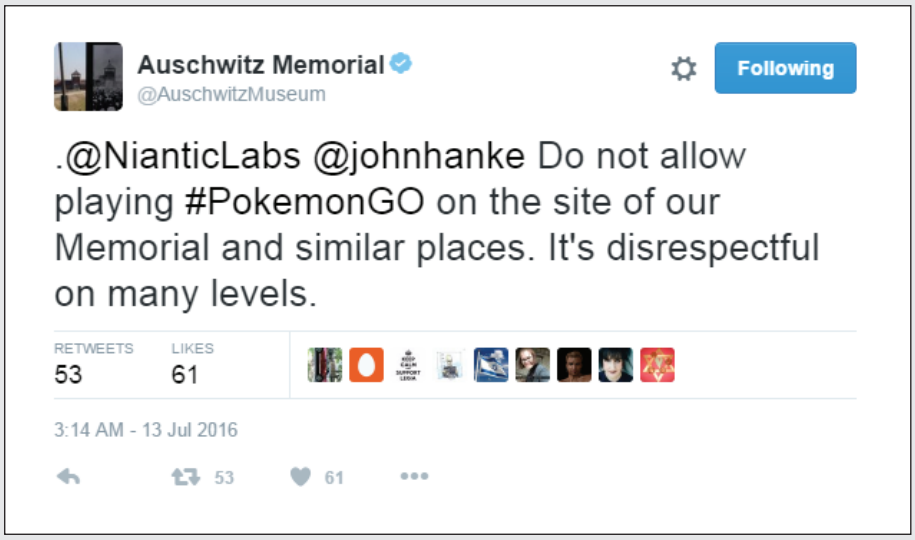


**FIGURE 1**
*As Pokemon could appear anywhere in the world, it was possible to play Pokemon Go at memorials, and have virtual Pokemon inhabit real physical spaces such as the Auschwitz Memorial. Via https://pokemorbid.tumblr.com/image.*

Other issues around the politics of space in Pokémon Go also emerged. Writing in Overland, Brendan Keogh (2016) makes the comparison between the experience of playing Pokémon Go and the 19th century figure of the flaneur, a figure from the work of Baudelaire – a typically socioeconomically privileged, white man who experiences urban space not out of the usual, purposeful motivations for movement, but through a kind of urban drifting or wandering. The comparison between the flaneur and the Pokémon Go player is, at the face of it, an easy one. Many found themselves wandering the streets with the hope of stumbling upon a rare and powerful Pokémon, moving around the city in ways that differed from usual motives.

But, Keogh notes that both the flaneur and the Pokémon Go player and their engagements with the city, are not free of politics. The politics of class, gender and race characterise these practices of moving throughout the city, much as they characterise playing Pokémon Go. As he puts it, "A nineteenth century woman would have a hard time being a *flaneur*," much would a non-white person in city spaces, people who are disproportionately targeted and profiled as potential threats by police. As Keogh puts it, "the non-white person who dares stroll around the city without clear purpose is seen as suspicious, as a loiterer, and might attract the attention of law enforcement – attention that continues to be a potentially deadly affair for black men in Western countries".

The broader politics of these spaces – grounded in geospatial technologies which have histories of capture and control for the US military – often also go overlooked. Niantic has its roots as CIA-backed geomapping software company Keyhole Inc (led by current Niantic CEO John Hanke). Keyhole was responsible for developing defence mapping software for use in the Iraq war. In 2004, Keyhole was acquired by Google and instrumental in the development of Google's mapping software, Google Maps – a now heavily monetised wayfinding application.

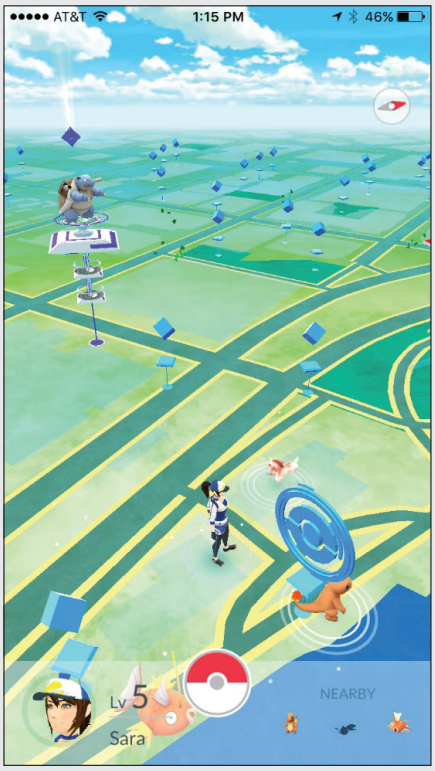


**FIGURE 2**
The ingame map of Pokémon Go – showing the locations of various nearby Pokémon (for players to capture) and Pokéstops (where players can replenish their ingame resources). The map data is derived from crowdsourced mapping software OpenStreetMap.

# ACCESSIBILITY, INCLUSIVITY AND EXCLUSION

Although VR/AR is often posited to be an accessible medium (in large part due to its 'natural' or intuitive UI), there is an emerging literature that focuses on how these media are less accessible than they may initially seem. We found a mixture of critical literature identifying issues with accessibility, inclusivity and exclusion, but importantly also literatures providing concrete directions for developers to take some responsibility in developing more accessible VR and AR. We noted two main themes in the literature around the topic of accessibility and exclusion. The first to do with disability and accessible design, and the second to do with the masculinised and toxic cultures surrounding VR.

There is a small literature – mostly in public writing and the field of Human-Computer Interaction – about VR, accessibility and disability. Several of these papers note that VR, despite being framed as having a more 'natural' UI – in the sense that it relies on movements and gestures of the body – it is not necessarily something that is intuitive or natural to *all* bodies. Specifically, the bodily interface for most VR devices presents accessibility issues for people with disabilities (PWD). For example, unlike Steam VR devices, the Oculus Quest does not allow the user to manually change the height of their avatar (Hicks, 2020). The result is that games, expecting an able-bodied standing user, will cause perspective problems, having characters talking over the user's head, and creating difficulties with aiming weapons. Much of the literature here makes claims about accessibility that are common to critical disability perspectives on technology (see e.g. Ellis and Kent, 2010; Newell and Goggin, 2002) – which focuses on how ableist and exclusionary values get encoded into the design of technology, which limit the capacities of people with disabilities.

Some work in HCI present solutions to this through bespoke controllers/interfaces. For example, Zhao et al. (2018) identify a range of accessibility issues with VR, proposing the use of a 'cane' controller for blind users. Wong et al. (2017) report on survey research about 79 PWD experiences of VR (including mental and physical disabilities) concluding that mainstream VR technologies are ableist and exclusionary in their design. Uniquely, Wong et al. engage survey participants to discuss what they see as necessary amendments to VR, while also addressing the techniques used by PWD in adapting to commercial VR's exclusionary design (e.g. one participant notes having to turn up sensitivity of the hardware as to not need to move one's head as rapidly, minimising physical pain). Further, this was also the only study that engaged questions of disability as intersectional. One respondent notes the relationship between representation and the minimisation of feelings of anxiety: "Also as a trans person, *different secondary sexual characteristics is surprisingly important*…giving me a body that looks like a man's is instant trip to physical nausea these days in VR..." (Wong et al., 2017, p.24).

Elsewhere, Mott et al. (2019) suggest five key forms of accessibility needed in current VR; content accessibility (e.g. introducing baseline features like the ability to change text size), interaction accessibility (accounting for different bodies by allowing different forms of gestural input for those with limited mobility), device accessibility (developing hardware that is accessible by a wider range of bodies, or at least offering the option to reconfigure it as to be appropriate for PWD), inclusive representations (e.g. diversity in avatar creation to include those with disabilities), and application diversity (offering a range of different applications, e.g. those for gaming, education, democratising access to VR as a broader medium). In a similar vein, a report by AbleGamers (Ryan, n.d.), a disability advocacy group for videogames presents a comprehensive breakdown of accessibility issues. These are:

- VR heavily emphasises motion controls. Not all users can perform requisite gestures required (e.g. the rapid movement of one's hands)
- VR requires very specific body positioning, and may otherwise not function correctly
- VR is a broad category of technology and spans a range of different hardware, thus making universal standards for accessible VR design difficult
- Hardware is not accessible to all users. Ryan gives the example of the headset, which can be difficult for some users to put on and remove. This in turn makes dealing with issues like software crashes difficult.
- VR places heavy emphasis on gaming. Ryan suggests more VR 'experiences' (rather than mechanically and gesturally demanding games) as a way to address accessibility issues
- VR privileges the visual and the gestural – yet, Ryan argues, audio receives much less designer focus. Audio can be used to make up for some users' inability to respond body in particular ways (e.g. turning head fast enough to see something).
- VR is often tested by able-bodied users. Incorporating PWD into the process of testing VR software and hardware could offer a way to prevent oversight in design in future

Beyond addressing accessibility issues, we also found work situating VR as a means through which to foster empathy for people with disabilities, by allowing users to experience other bodies (see Pivik et al., 2002). Kalyanaraman et al. (2010) provide an example of this in their study of VR as an effective medium through which to foster empathy about schizophrenia. As we point out later, drawn out from literature on social empathy (see e.g. Hassapopoulou, 2018), it is important that to avoid playing into reductive views of marginalised groups (here, PWD), it is important that such experiences incorporate PWD perspectives into the design process (for various examples of PWD designed experiences, see Couch, 2016).

A body of work also focuses on AR and disability. A large portion of this work – largely emerging from HCI and cognate fields – dealt with AR as assistive technologies for people with cognitive impairments. As Blattgerste et al. (2019) note, in their extensive literature review of HCI-related research on AR and disability, studies within the field have been attentive to AR's potentials for action assistance and learning, in both children and adults with disabilities. In terms of learning, for instance, AR applications using handheld devices (Brandao et al., 2015; Chen et al., 2016) and wearable smartglasses (Liu et al., 2017; Sahin et al., 2018) help to develop cognitive and social skills in children with autism. Elsewhere, studies frame AR in terms of its capacity for action assistance – used in contexts like wayfinding (Smith et al., 2017) and work (Funk et al., 2015; Korn et al., 2013).

Yet there is no reference in this HCI work, and little elsewhere, about the often ableist and exclusionary assumptions made by designers of AR technologies that exclude participation and use by PWD. Some public commentary has emerged in this space on the topic of AR

mobile gaming. Writing on the example of Pokémon Go, Alexander (2016), in interview with AbleGamers' Steve Spohn, spotlights how this AR game is designed in such a way that is encoded with ableist assumptions about the user. Spohn suggests that the game's basis in players' physical movement meant that it was inaccessible for those with limited mobility. Spohn also points out some further general accessibility issues to do with mobile based AR, such as a lack of voice-activated controls for those with poor vision or blindness. The points Spohn makes here dovetail with some existing academic work on disability and mobile interfaces (see e.g. Goggin, 2017a), which point out how mobile interface designers typically neglect intentionally designing for disability.

Another important dimension of issues with accessibility and inclusion in mixed reality is around gender. In the literature, we found a substantial focus on gender-based discrimination, harassment and bias. This is both at the level of experiencing gameplay, but also more broadly in terms of the gendered biases that surround its production and get designed into the technology.

Sexual harassment in virtual spaces was a key theme noted in critical discussions of gender and VR. One of the most prominent early pieces of writing in this vein is Belamire's (2016) blog post outlining her experience of sexual assault in the form of "virtual groping" in social VR archery game QuiVr (2016), describing the experience as something that was very real in terms of its felt effects. Belamire's experience, as a survey of VR users' social experiences (Outlaw and Duckles, 2018) points out, is not uncommon. For surveyed users of VR on the HTC Vive, Oculus Rift, Playstation VR and Microsoft Windows Mixed Reality, 49% of female and 36% of male respondents reported experiencing some form of sexual harassment.

Consistent with Belamire's account, Katherine Cross has suggested we take seriously VR based sexual harassment as a form of sexual harassment, arguing "the mediating interface of a game does not make abusive behaviour between two or more real people any less abusive. Slurs are still slurs; unwanted sexual advances are still both unwanted and sexual" (Cross 2016). Despite this, as Cross notes, responses to Belamire's VR harassment tended to downplay its severity due to its digital setting and place the onus on the victim to end the experience, suggesting "she could easily turn off, or just 'take off her headset' to escape" (2016).

Several works have since further explored how virtual harassment does have the potential for real harm. Murphy (2017) suggests that VR is a medium through which "the player's body is a meaningful and easily-accessible site for delivering feedback" (2017, p.14), and as such, proxemic effects "are perceptually and cognitively analogous to real-world vision and audition. For emphasis, it is worth restating that virtual humans standing too close to VR users can be experienced as uncomfortable or distressing" (2017, p.14). From a legal perspective, Danaher (2018) works through various definitions of what constitutes assault, applying this to think about VR, ultimately concluding that harassment in VR can constitute sexual assault. Danaher flags that VR poses issues surrounding consent and recommends creating clear and unambiguous forms of signalling consent. For Wood et al. (2017) the issue of clearly signalling consent in VR is further echoed. In addition, they also suggest that VR represents an intensification of existing issues with sexual harassment and technology (e.g. the creation of VR based digital representations of bodies, continuing the problematic tend of deepfakes). For Blackwell et al. (2019), drawing from survey and interview research, harassment and discomfort is prevalent in social VR experiences. They suggest that rife harassment might stem from both VR's entanglement with masculinised and often toxic 'gamer' culture and the interactive and immersive nature of VR itself. It's worth noting, as Blackwell et al. do in their limitations, that their study was unable to recruit more women and nonbinary users

into their sample, and as such deals largely with the experiences of male users. Despite limitations, they provide a useful framework for thinking about different kinds of VR mediated harassment – paying attention to the specific affordances of the VR medium (see Blackwell et al., 2019, p. 12). These are: 1) verbal harassment (personalised insults, such as hate speech or sexualised language, transmitted through VoIP or private messages), 2) physical harassment (such as unwanted touching or making visible sexual gestures, signalled through the movement of one's avatar), and 3) environmental harassment (displaying sexual or violent content in the virtual environment, such as creating and sharing sexually explicit virtual drawings). Blackwell et al.'s (2019) account is of increasing relevance given its specific focus on harassment within social VR which is increasingly the focus of companies like Facebook.

So far, we have focused largely on sexual harassment to do with interactions between human users. Offering a different perspective, Franks (2017) outlines how engagements with non-player characters in VR spaces might also be cast as problematic and contributing to an affirmation of sexual harassment in VR, giving the example of the game Dead or Alive Xtreme 3 on Playstation 4's VR – which allows players to grope the game's bikini clad non-player characters while she grimaces, protects her body with her arms, and says "I don't like it". In the video demo shared online that precipitated media attention, the male-sounding audience laughs in response. As Franks writes "The primary concern with games like these is not the harm one user inflicts on another actual user in a virtual reality environment, but the harmful habits the technology encourages the user to indulge" (2017, p.528). As Buckley (2016) puts it, Dead or Alive Xtreme 3 is "basically sexual assault the game" (n.p.), and the dedicated VR 'porn game' is a growing genre, with many depicting – or focusing on – sexual assault fantasies.

Beyond sexual harassment, there are other issues to do with gender and the design of accessible VR experiences. As boyd (2014) provocatively asks, "is the Oculus Rift sexist?" – describing the physical side effects of nausea felt by herself and other female colleagues in using Oculus's VR. She suggests that the cause is humans using 'depth cues' to determine how far away objects are. boyd elaborates, noting that there are two main kinds of cues, 'motion parallax (which tells the brain if an object is getting larger it is also getting closer) and 'shape-from-shading' (which gives the brain a sense of an object's distance due to the way light is cast on an object). Crucially, boyd argues, as motion parallax is easier to replicate, VR systems primarily rely on motion parallax cues. The problem with this, as boyd notes, is that men tend to prioritise motion parallax cue while women rely more on shape-from-shading. These key physiological differences in gender have not been taken into account in the design process resulting in issues of accessibility – a case highlighting the importance of incorporating a more diverse range of perspectives into the design of VR (and technology more broadly). More recent empirical work has found that women are at greater risk of motion sickness from VR (Munafo et al. 2017), which has significant consequences in terms of access and inclusion as VR becomes more widely available and used in contexts like education, and that women are underrepresented as participants in VR user studies and as authors of VR research (Peck et al. 2020).

Scoping out, there are wider structural issues that clearly point to this culture of toxicity and sexism around VR. As Blackwell et al. (2019) and Harley (2019) point out, VR's emergence can be situated within a milieu of misogynistic videogame culture and reactionary right political views – views famously held by Oculus founder Palmer Luckey. In such a way, VR as conceived by Luckey is taken to represent freedom and autonomy – something that has benefits for CIS-male users like Luckey, but not for the female users against which the technology is weaponised.

# CASE STUDY TWO
# QUIVR AND THE REALITY OF VR SEXUAL HARASSMENT

Much like other virtual spaces – such as videogames and social media – VR is one that has the potential for hostility and harm toward female users. This potential was made abundantly clear in Jordan Belamire's experience in playing the fantasy themed first-person shooter QuiVR, detailed in a blog post titled 'My first virtual groping' (see Belamire, 2016).

She writes, "In between a wave of zombies and demons to shoot down, I was hanging out next to BigBro442 [another user in the game], waiting for our next attack. Suddenly, BigBro442's disembodied helmet faced me dead-on. His floating hand approached my body, and he started to virtually rub my chest" (2016, n.p.) She goes on to detail her response. "'Stop!' I cried. I must have laughed from the embarrassment and the ridiculousness of the situation" (2016, n.p.). But, as she goes on to note, "The virtual groping feels just as real. Of course, you're not physically being touched… but it's still scary as hell" (2016, n.p.). The account Belamire provides is reminiscent of earlier observations about virtual harassment, specifically, Dibbell's well-known article 'A rape in Cyberspace' (1993) in which a user, expert in the affordances of a text-based virtual environment, non-consensually mediated sexual encounters between other players and themselves – something no less harmful despite there being "no bodies touched" (Dibbell,1993, n.p.).

VR based sexual harassment, Belamire outlines, is particularly problematic due to how VR affords the user an immersive, auditorily and visually rich experience – something that is often framed as a key, positive characteristic of the medium. What, then, can be done to redress these forms of mediated harassment?

Following Belamire's article, QuiVR's developers responded by providing users more power over their (virtual) personal space, writing that "If VR has the power to have lasting positive impact because of that realism, the opposite has to be taken seriously as well" (Jackson and Schenker, 2016, n.p.). They discuss changes made to QuiVr following the publication of Belamire's account, such as including a 'personal bubble' feature that means that other players 'fade out' when they reach to grab or touch another. Katherine Cross (2016) notes their "elegant solution" (n.p.) highlights how the potential for harassment in VR should be dealt with by developers as part of the standard quality assurance process. Unsurprisingly, many online VR games still do not have such features – and is something that developers must much more proactively consider in future.

# SURVEILLANCE AND PLATFORM POWER

The theme of surveillance/platform capitalism was also noted across work discussing the ethical implications of Mixed Reality. To broadly define these terms, often used within critical political economy of contemporary digital capitalism, platform (Srnicek, 2017) and surveillance (Zuboff, 2019) capitalism typically describe the business practices of digital platforms and companies that use or manufacture forms of digital sensors. A heavy emphasis is placed upon the accumulation and expropriation of user data as a mechanism for profit, but also power. As Srnicek notes, many platform companies have – through expansive, cross-subsidising practices – moved into the sale of various forms of digital sensors. This allows for the reduced price of a service or good (often free, such as in the case of Facebook) leading to more users, allowing for money to be made elsewhere (i.e. via data). Platforms acquiring things like VR/IoT tech provides them with granular data that may otherwise not be available, which can subsequently be monetised by that platform owner. As we have noted in Egliston and Carter (under review), the full effects of this are yet to be felt, with Facebook so far mobilising its Oculus data for targeted advertising based on use of VR software.

In our literature review, there was a small body of academic and non-academic work focusing on Facebook's acquisition of Oculus. In their media-historical approach to Facebook, Helmond et al. (2019) discuss Facebook's 2014 acquisition of Oculus as occurring within Facebook's post-IPO process of infrastructural expansion and acquisition – and represents an instance of what Srnicek (2017) describes as the expansive and extractive nature of platform capitalism (as we argue in Egliston and Carter, under review). Rose (2018) specifically addresses Oculus and Facebook capturing data. Indeed, while Facebook have claimed to only be using information about user software used in order to target users with VR related advertising (see Kan, 2019), considering Facebook's history of unscrupulous business practices (e.g. their privacy violations around facial recognition, see Singer & Issac, 2020), these concerns should not be dismissed as exaggerated or alarmist.

While the effects of VR as a mechanism for surveillance capitalism have not yet been fully felt, and much existing commentary and critique is anticipatory, its potential is very real. Bailenson (2018) underlines this in discussing VR as a sensor with the potential for capturing granular data about the body. He writes, "commercial systems typically track body movements 90 times per second to display the scene appropriately, and high-end systems record 18 types of movements across the head and hands. Consequently, spending 20 minutes in a VR simulation leaves just under 2 million unique recordings of body language" (2018, p.1). In light of VR operating as a sensor technology, now mobilised by Facebook, Outlaw and Persky (2019) suggest that proactive moves toward

regulation are crucial. Specifically, they suggest the formation of independent ethics review committees overseeing future VR development.

Other questions have emerged about VR and platform capitalism, specifically to do with what Nieborg and Poell (2018) call the 'platformisation of cultural production'. This describes a dynamic where platform owners attempt to encourage widespread use, and eventually dependency upon their platform. In Egliston and Carter (under review), we discuss the platformisation of cultural production around the example of Facebook and Oculus. Specifically, we look at the way that the technology is made to appeal to not only end-users, but platform developers, such as through a Software Development Kit that can be integrated into popular game engines like Unity and Unreal. As Foxman (2018) notes elsewhere, other big tech companies operating in the MR space, like Google and Microsoft, likewise offer SDKs for use with Unity, and Microsoft is increasingly positioning the Windows operating system as a 'holographic computing platform'.

Literature on augmented reality similarly touches on themes of surveillance and platform power. Zuboff (2019) gives some attention to the AR game Pokémon Go, suggesting it is a mundane example of surveillance capitalism, that is, how the accumulation of data about almost all aspects of everyday life is part of a recent and deeply corrosive tendency of capitalism. As Zuboff notes, AR games/software operate as digital sensors that track spatial/geographical movement, and can be leveraged by surveillance capitalists in order to drive behaviour in certain ways (e.g. location data as a way to drive business traffic; partnered locations etc. See also Iveson, 2016; Leorke, 2018, p. 113 on Pokémon Go). As a journalistic article by D'Anastasio and Mehrotra (2019) points out, Niantic capture granular locational data about users in their games (here about Harry Potter: Wizards Unite). "Because the location data collected by Wizards Unite and sent to Niantic is so granular, sometimes up to 13 location records a minute, it is possible to discern individual patterns of user behaviour as well as intimate details about a player's life." (D'Antasasio and Mehrotra, 2019, n.p.). There are also pertinent questions about how the accumulation of data by Niantic in its previous games was used to develop maps for Pokémon Go (Goggin, 2017b; Leorke, 2018, p. 146) – in this way raising concern about the intersection of gameplay and labour. Similar claims were made about other mobile-based AR software – such as FaceApp (Fussell, 2019). The point here is that FaceApp captures and expropriates facial data, yet the author suggests that this is a relatively minor part of a much larger culture of surveillance capitalism (making reference to larger industry players such as Facebook). Pesce (2017) suggests that there are questions about data ownership and questions about how data is being used by large tech companies (for instance in the training of machine learning algorithms), which becomes increasingly granular as the capacities of AR develop further.

We also note issues to do with the capture of data about space itself (rather than people's movement through and use of space). AR (and mobile VR, such as the Oculus Quest) – in order to register movement and space – are reliant on simultaneous localisation and mapping (SLAM), that is, the construction of a digital map of the environment the device is located within. Through SLAM, which can register information about indoor or underground spaces – irretrievable through satellite navigation (GPS), AR and VR companies are given more than just location data, but rather (granular) data about locations. Facebook's recent proposition for 'live maps' – a user generated mapping technology first described at Oculus Connect 6 – is a key example of the services imagined based on the potential of this vast scheme of data collection (see Oculus, 2019a, 2019b).

# CASE STUDY THREE
# MAPPING THE WORLD: FACEBOOK, SLAM AND LIVEMAPS

Facebook's 'Oculus Insight' – its virtual-inertial SLAM – is a key component of its current VR technologies (e.g. the Oculus Quest), and how the untethered headset locates itself within a physical environment. Insight's "ultimate goal…is to deliver AR and VR experiences that are not only more immersive but also integrated into the physical world" (Oculus, 2019a). These ambitions were made abundantly clear in September 2019 – when Facebook's Andrew Bosworth introduced 'Live Maps', an everyday AR feature described at OC6 as using:

> *…machine perception to construct multi-layered representations of the world, showing where you are in space, recognising what things look like, and understanding the intrinsic meaning of objects. Connected devices, like smartphones and AR glasses, will scan the surroundings to create a live dynamic index amplified by crowd-sourced data, allowing the maps to recognise when things have changed and update automatically.* (Oculus 2019b, n.p.).

Such a system demands constant and finely detailed data collection about the users' physical environment, and the things within it. Reflecting this ambition of data accumulation, Facebook also acquired UK Augmented Reality company *Scape Technologies* for USD$40 million in February 2020, a company that creates renderings of the world to enable "centimetre level location recognition" (Sterling, 2020). This description of Live Maps, and the depictions of how it will add convenience to the lives of Facebook users, emphasise how Big Tech envision the opportunities associated with the unprecedented richness of data captured by SLAM-enabled technologies like VR and AR headsets.

The depictions of how Live Maps will add convenience to the lives of Facebook users emphasises how Facebook envisions the creation of new services only possible due to the unprecedented richness of data captured by MR wearables. Everyday interactions, such as enhanced wayfinding already seen in Google Map's rapidly expanding mobile-AR features already rolled out on smartphones, hint at how this data accumulation will be applied to direct and monetize user's attention in the physical world in the ways envisioned in Keiichi Matsuda's dystopian *Hyper Reality* (Matsuda, 2016, see Figure 3). In the vision of an AR future Matsuda paints, our environments are overlaid with a constant feed of information – much of which advertising – serving the interests of powerful tech companies, who currently derive profits in this way via the data captured through internet search and mobile data. But beyond the modulatory power of these interfaces to

serve the logics and motives of advertisers at social media companies like Facebook – the capture of granular information about our homes and our cities also shows the potential for a harder, more harmful wielding of these technologies. It is not hard to imagine these technologies being co-opted by the state (through partnerships between the state and big tech companies), complementing existing state enacted cartography (see Leszczynski, 2012. We elaborate on this further in Case study Four)

**FIGURE 3**
**Above**, Facebook's rendition of a MR livemaps future as shown in an advertisement at Oculus Connect 2019. **Below**, Google Map's AR features and Facebook's Live-Maps technology may enable the dystopian vision of pervasive Augmented Reality, as envisioned here in 'Hyper Reality' by Keiichi Matsuda (2016)

# THE MILITARY-ENTERTAINMENT COMPLEX

There is a long history of connections between the US military and the development of MR technology. This is part of a wider and historically longstanding relationship between state bodies like DARPA (the R&D wing of the US Department of Defence) and technology companies (see e.g. the development of the internet as military technology), a relationship known as the military-entertainment complex.

Crogan (2011) provides an account of the close connections between videogame technologies and developments in military technoscience and war-fighting R&D. Part of his analysis pays attention to virtual reality, specifically Sutherland's development of the first HMD in the 1960s, used by the air force. On AR, Davies and Innocent (2017). Goggin (2017b) and D'Antasio and Mehrotra (2019) suggest that spatial software used by Google Maps (originally developed by Keyhole Inc), and in Pokémon Go, was initially backed by the CIA's venture capital firm In-Q-Tel. While such mapping technology was used commercially for AR gaming, it was also used as a warfighting technology by the US in Iraq in the early 2000s. As such, commercial AR technology is situated on a wider lineage of military R&D. As Crogan writes – in his more philosophical look at the military entertainment complex – the outcome of this is that we're living in a 'permanent' wartime (2011).

Elsewhere, others make connections between AR technology and other apparatuses of the state. Andrejevic (2017), for example, as part of a wider account of automation, digital technology and policing, suggests that camera-equipped AR smart glasses (for facial recognition, licence plate recognition, etc.) operate as a mechanism of state control and power. This narrative fits with recent developments, such as Microsoft weaponizing their AR HoloLens for military use (see Ghaffary, 2019; Hollister, 2019). Recently, as one of the many technological responses to the COVID-19 pandemic (e.g. drones, 3D printing, etc.), AR has been deployed by the state in order to attempt to identify and limit the spread of potential vectors of contagion. This has taken place in China, Italy and the UAE, through the use of technologies developed by Chinese firms like Rokid or Kuang-Chi Technology (see Bright and Liao, 2020; Melnick, 2020; Reuters, 2020). Examples of these technologies include Kuang-Chi Technology's KC-N901 smart helmet, or Rokid's AR smartglasses. Both technologies purport to record and display information about individuals within the users' view (notably, body temperatures) – and represent part of a much larger COVID-provoked boom in an industry of consumer-grade thermal imaging (see Gershgorn, 2020). Beyond these cases, American AR hardware manufacturer Vuzix has recently announced collaboration with AR software platform Librestream to similarly provide thermal imaging tech in response to COVID (see Horwitz, 2020).

The case of AR and COVID-19 is particularly interesting in that it represents the potential for the largest scale mobilisation of AR by the state to date. Due to the ongoing nature of the pandemic, there is no existing critical work about AR specifically as a surveillance apparatus for biosecurity. Critical accounts of COVID-19 surveillance tech more broadly can, however, be extrapolated (e.g. Richardson, 2020 on drones). As Richardson suggests, drones as a form of sensor tech may very well be effective solutions to the problem of a global pandemic – identifying social vectors of transmission and mitigating their impact. But as the rollout of these invasive sensing technologies by law enforcement likely intensifies, we must remain lucid about their long-term impacts on our civil liberties should they become a normalised part of social life. Much the same can be said for invasive AR technologies.

# CASE STUDY FOUR
# MIXED REALITY, THE STATE, AND BIOPOLITICAL CONTROL

Mixed Reality technologies also have the potential for the biopolitical management and control of people (via Foucault, see Adams, 2017). This refers to the ways that MR as digital sensor has the potential to work as something that is mobilised (or potentially weaponised) against a population, as has been the case with surveillant technologies like CCTV, and more recently biometrics and facial recognition – technologies which disproportionately target the most vulnerable and marginalised groups in society.

This potential surveillant possibilities of Mixed Reality is exemplified in recent interest in employing thermal imaging (particularly in warehouses, see Gershgorn, 2020) in response to the COVID-19 pandemic; with some employers in the US expressing interest in the use of MR wearables to administer this surveillance (see Bright and Liao, 2019).Through the potential for the invasive surveillance of bodies – extending an already existing mobilisation of biometrics in the workplace – power dynamics have the potential to be further skewed in favour of those administering these apparatuses of surveillance. For example, if we are to take seriously claims about MR technologies as offering granular information about the body – from iris tracking to electrodermal activity – how might these technologies subvert legal protections against employer-mandated health and medical testing?

The installation of a harder, militarised regime of biopolitical power, violence and repression – by the state through partnership with MR technology companies – is also not hard to imagine. Once again using the case of the COVID-19 pandemic, MR has been used for tracking the bodies of individuals – specifically, body temperature, using MR thermal imaging. We see this in the use of Rokid's AR smartglasses by police and private security to track citizens' body temperatures in China (Bright and Liao, 2020), or the use of KCWearables' thermal imaging helmet in the UAE (Reuters, 2020). While the argument can be made that this is a helpful short-term measure to identify vectors of infectious disease, they show the potential use of these technologies for control of social life more broadly. And indeed, this is a future that is not too distant.

We begin to glimpse this future through adoptions of MR by the police and military. For example, the controversial facial recognition platform ClearView AI (which is already being licensed to law enforcement agencies

**FIGURE 4**
AR smart helmets in use at the Duomo di Milano, Milan, during the Covid-19 pandemic. These devices can scan crowds of people and trigger an alarm, despite the limited evidence supporting temperature screening as a preventative measure (Ghosh, 2020). The same devices have automatic facial recognition modes and other surveillance capabilities. Image via Milano Today (Guarino, 2020)

in countries like the US and Australia) has reportedly tested their software with AR wearable Vuzix (Cameron et al., 2020). Vuzix has previously touted its potential for 'security' applications – such as in its partnership with American security firm SWORD. As a press release notes, "SWORD is a customizable solution for security teams or task forces. Housed in its own case, SWORD uses a combination of proprietary sensor fusion technology to detect concealed weapons and run facial recognition against cloud-based databases. Ultimately, it can do this in a matter of seconds. Threats and notifications detected by SWORD will be pushed directly to the heads-up display in Vuzix Blade smart glasses" (Vuzix, 2019, n.p.).

Returning to the setting from which it emerged, we can also note the potential for MR as advancing regimes of violence in its adoption by the military. AR HMD component manufacturers like Kopin and Elebit (both of whom develop commercial AR products) currently develop AR displays for the US Air Force's F-35 fighter jets. Another particularly high-profile case of MR and the military is Microsoft's recent $480M contract with the US military (see Hollister, 2019) to develop a HoloLens style 'Integrated Visual Augmentation System' for use for military combat and training. Further blurring military and consumer technology, a 2018 patent for Microsoft's AR smartglasses – an in-progress vision of a more portable HoloLens – there is once again emphasis on MR's military applications, showing the potential for the relay of information between military personnel.

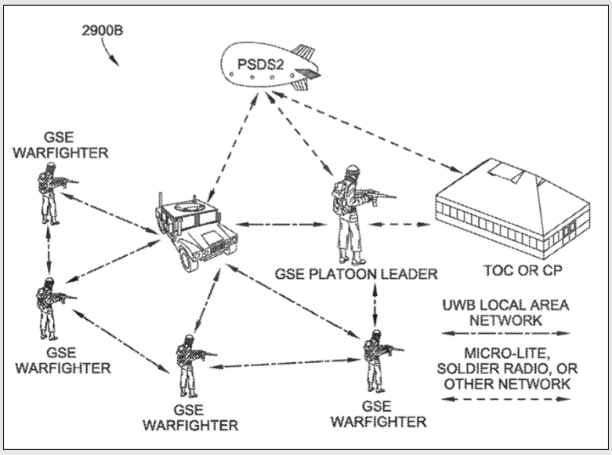


**FIGURE 5**
Image from Microsoft's patent for a HoloLens style set of smartglasses, highlighting its potential as a communications tool for soldiers. See https://patents.google.com/patent/US20120194419

# EMPATHY

There is much uncritical industry boosterism around VR which positions VR technology as 'empathy machines' (a term coined by VR filmmaker Chris Milk). The idea here is that VR mediates a kind of empathy or compassion for others. As Milk puts it, in discussing the (UNICEF and Samsung sponsored) VR film 'Clouds over Sidra', VR is "a machine, but inside of it, it feels like real life. It feels like truth. And you feel present with the world you are inside, and you feel present with the people that you are inside of it with. When you are sitting there in … [Sidra's] room watching her, you are not watching it through a television screen, you are not watching it through a window, you are sitting there with her. When you look down, you are sitting on the same ground as she is on. Because of that you feel her humanity in a deeper way. You empathise with her in a deeper way … VR is a machine, but through this machine we become more compassionate, we become more empathetic, we become more connected, and ultimately we become more human" (Milk 2015).

A range of academic literature generally contests Milk's claim. Bollmer (2017) develops a theoretical argument against the claim that VR mediates empathy. Bollmer argues that 'empathy' is reliant on a flawed neuropsychological assumption that we can 'know' the experience of another, and that the kinds of affective, sensory experiences afforded by VR are often conflated with this flawed understanding. Hassan (2020), has elsewhere argued against the fallacy of thinking VR as an empathy machine – suggesting that VR experiences (focusing particularly on VR journalism) does not have an equivalence to the "innate physical and cognitive capacities and limitations" (2020, p. 200) of the human user, and thus cannot be generative of empathy.

Instead, Bollmer proposes the concept of *radical compassion* to understand VR's power in this regard.

Elsewhere, Rose (2018) suggests that it is difficult to disentangle this humanitarian, tech-for-good purpose from the clear ethical concerns surrounding privacy/surveillance associated with VR. Nash (2017) also contests the 'empathy machines' argument by suggesting that VR brings the audience into a relationship of 'false proximity' with the subject, suppressing or diminishing any actual critical response to the documentary content. Others take approaches more attuned to cultural hegemony. Hassapopoulou (2018) suggests that VR's empathy narratives are based on a deeply undemocratized process of software development, where narratives are typically not coming from the groups or individuals from these communities depicted, but rather from individuals in the media and technology industries. In this way, Hassapopoulou encourages thinking about how VR – understood as an 'empathy machine' – galvanises dominant cultural narratives and images, through a medium that is 'exclusionary and elitist' (see also Irom, 2018). In a similar vein, Sam Heft-Luthy (2019) points to Talespin's workplace 'empathy training' technology demo – in which the user fires a 'virtual human' Barry, who sobs, or reacts angrily depending on the users' approach – to highlight how 'greater empathy' is simply a tool for the managerial class to resolve the affective harm to workers under capitalism, while continuing the underlying exploitation.

# CASE STUDY FIVE
# THE ULTIMATE EMPATHY MACHINE?

Virtual Reality technologies are often described by VR industry boosters as 'empathy machines', a term popularised by VR filmmaker Chris Milk in his 2015 TED Talk (Milk, 2015). In contrast to film – which only provides the viewer a 'window' – Milk contends that VR allows the viewer to 'step through the window' and become a part of the virtual world, with transformative potential. Framing VR in this way is not unique; most emerging media have been theorized as having the potential to extend the human ability to connect with the inner life of another being (Heft-Luthy, 2019), but treating this potential uncritically can be ethically fraught.

Bimbisar Irom (2018) analysed two VR films that attempt to convey the experience of refugees, including one by Chris Milk; *Clouds over Sidra* (Arora & Milk, 2015) and *For My Son* (Temple & Ingrasci, 2016). In humanitarian films like these, the appeal of VR lies in the possibility that VR can bridge the gap between the real and mediated experience, crucial for motivating aid and action. Yet Irom's analysis highlights how the medium of VR is still subject to the same "constraints of ideology and power hierarchies" (p. 4287) that are evident in other representational tools such as film, including the prevalence of stereotypical images; the challenge of how to address the invisibility of refugees where their voices are only heard after they pass through ideological frames that perpetuate existing inequalities; and who places the camera, and where. A greater sense of presence does not remove these constraints, and at worst may even conceal them from view.

**FIGURE 6**
Chris Milk – a creator of Clouds over Sidra, a VR film about the Syrian refugee crisis – has suggested that VR is an empathy machine, but critical work has questioned this suggestion.

# WORK

AR promises utility as an assistive technology within the workplace, particularly within the manufacturing industries. There is a body of research in HCI that presents experimental cases – with Funk et al. (2017) noting that few have made the leap from lab to industry (although citing some exceptions, such as the in-situ projection-based Light Guide System from OPS Solutions). As Funk et al. (2017) point out, AR interfaces have been used in some capacity since the early 1990s, specifically in aerospace engineering (see Caudell et al. 1992 cited in Funk et al., 2017). A range of research to date has addressed the potential benefits of AR in manual assembly work – underlining its benefits in reducing error and cognitive load (Tang et al., 2003), in both abled and disabled workers, see Funk et al., 2015), providing task-relevant information (Henderson and Feiner, 2009). Little work has been done on the long-term evaluation of in-situ projection with the exception of Funk et al.'s (2017) study, which provides an account of in-situ AR interfaces in manual assembly workplaces, finding that such interfaces hindered the assembly speed of expert workers (e.g. increasing cognitive load), yet enhanced the efficiency of untrained workers.

Beyond experimental applications emerging from HCI research, technology companies have variously come to develop AR applications for the workplace. A range of AR hardware (e.g. Google Glass Enterprise Edition, Vuzix M400) and software (e.g. UpSkill) have emerged for use within workplace settings. As the Google Glass Enterprise edition website notes, the device is used within contexts of manufacturing (in the emerging 'smart factory') but also in logistics, and healthcare. We see this through examples like Boeing and DHL's respective uses of Google Glass. In one testimonial for the Google Glass, by American aerospace company Boeing, AR is framed as appending the limited capacities of the human worker (specifically, those installing electrical wiring on aircraft) – offering "real-time, hands-free, interactive 3D wiring diagrams – right before their eyes" (Boeing, 2018, n.p.).

Yet, despite big tech companies staking out a space in industrial settings, we have identified no existing literature (including non-academic writing) that critically addresses the implications of AR in the workplace, nor providing an account of the scale at which this technology is being used. As such, in order to think speculatively about AR's implications for work, we adopt a more permissive definition of AR here – such as that used by Wolf et al. 2018 – to include wearable sensor technologies (such as FitBits etc) rather than squarely focusing on head-mounted AR. We believe that this wider, existing literature shows the clear potentials for AR's impact on the workplace. We believe that many of these current issues are pertinent in a consideration of AR's future in the workplace.

Wearable devices that track user activity are a key part of contemporary work. As Moore (2018) suggests, this includes wearables as efficiency-tracking mechanisms for manual work in warehouses, or for corporate 'wellness' programs in white collar or office contexts. Such technologies were particularly widely problematised following news of Amazon's use of tracking wearables for employees in warehouses, specifically, a wristband "which gives it the ability to track and record employees' hands in real time" (Salame, 2018, n.p.).

A range of work has developed critical responses to the movement toward tracking and quantification in the workplace. From the perspective of sociology and critical theory, Till (2019) suggests that the deployment of smart tech in corporate workplaces – and the veneer of corporate 'wellness' that they carry with them – works as a mechanism for control. Drawing from French philosopher Bernard Stiegler, Till argues that we might think of corporate tracking as a mechanism for shaping people's psychic and libidinal energy (accruing benefits to companies) rather than for stated material health outcomes. Critics elsewhere have compared quantified work to Taylorism (Morozov, 2013; Salame, 2018), that is, an approach to applying experimental measures to enhance managerial control of worker efficiency – or an 'updated' form of Taylorism (as Moore, 2018 has it). On the effects of such regimes of quantification and tracking in the workplace, Moore writes "we can speak of declining welfare for workers and the associated regime of total mobilization and surveillance as they corrode workers' health and safety, and create anxiety, burnout and overwork" (2018, p.55). Moreover, she notes "Capital is tempted to invest in new technology not because it may improve the public good, regardless of the rhetoric of wellness that informs current wellbeing initiatives for workers, but rather because it can increase its profit ratios" (2018, p.56). Offering a different take, O'Neill (2016) suggests that quantified work resembles not Taylorism, but rather a distinct style of worker management referred to as the 'European Science of Work'. The distinction, O'Neill argues is that the wearables and sensors mobilised in quantified workplaces do not simply attempt to intensify the body as to be more productive (as per Taylorism), but rather to manipulate the production process as to "better accommodate biological processes of fatigue and regeneration" (2016, p. 610), that is, better harnessing productivity through attention to the labouring body's rhythms.

As noted prior, despite the growing prevalence of head mounted AR hardware and software marketed for industrial use, we identified no existing research on the topic. Yet, we believe that there is clear potential for many of the same issues described in existing research on the quantification and rationalisation of work through wearable sensor technology to be played out through the introduction of AR into workplace settings. Notably, as we see from the experimental HCI research surveyed prior, as well as the examples of AR's rhetorical framing in the workplace (e.g. Boeing's testimonial for the Glass), there is similar emphasis on making the user a more productive subject.

# CASE STUDY SIX
# AMAZON, SURVEILLANCE AND CONTROL: THE FUTURE OF WORK?

In recent years, the material conditions of warehouse workers servicing Amazon's e-commerce arm have been subject to increasingly intense scrutiny. Workers in Amazon's so-called 'fulfilment centres' – the sites for the storage and delivery of products to customers – have widely reported conditions of surveillance and strict control. In an Australian context, Burin reports that warehouse workers are expected to work at 'Amazon pace' – "somewhere between walking and jogging" (Burin, 2019, n.p.). She notes that workers – many of whom are precarious, casual workers, hired by Amazon through labour hire agencies – are at risk of losing further employment should they not meet this standard. Intensifying this are reports of Amazon's use of surveillance technologies (such as wearable wristbands, see Salame, 2018) which tracks various forms of bodily activity – data which can be operationalised to say whether or not employees are being efficient enough.

MR technologies, largely HMDs and smart glasses, are beginning to enter workplaces – particularly within the setting of manual labour. In addition to catering to a commercial market, MR manufacturers like Microsoft, Google, Vuzix, and Kopin have 'enterprise' versions of their technologies aimed largely at the manufacturing and logistics industries. While these are often framed by industry boosters as a net positive – reducing human error, increasing efficiency and so forth, it is not difficult to see them harnessed (much like Amazon's wearables) to discipline and dominate, to maintain productivity through intimate surveillance of the worker's body.

**FIGURE 7**
Workers in one of Amazon's fulfilment centres. Retrieved form https://www.flickr.com/photos/99781513@N04/16278498935

# APPENDIX

## METHODOLOGY

This report presented a thematic literature review of interdisciplinary research and public writing (e.g. tech journalism, blogging) addressing the ethical issues inherent within studies of VR and AR. Scholarly material was located through the Google Scholar database, combining the following search terms. Given that we wanted to explore studies of VR and AR from fields like Human-Computer Interaction as well as humanities and social sciences disciplines, Google Scholar was appropriate. Google Scholar is better at identifying publications in the humanities and social sciences (such as book chapters and books) than databases like Scopus or Web of Science (see Martín-Martín et al., 2018). We also looked at the citations contained with these references, resulting in the discovery of a number of further publications that we reviewed and included in our literature review.

Search terms (in Google, Google Scholar) included combinations of:

- Virtual reality
- VR
- Augmented reality
- AR

and

- Ethics
- Pokémon Go ethics
- Surveillance
- Privacy
- Disability
- Accessibility
- Data
- Facebook Oculus data
- Law
- Legal
- Ethical frameworks
- Ethical design
- Ethical use
- Gender
- Harassment
- Work
- Labour
- Quantified work
- Safety
- Military
- Empathy

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