When Virtuality Surpasses Reality: Possible Futures of Ubiquitous XR

Ross Johnstone
Ross.Johnstone@glasgow.ac.uk
University of Glasgow
Glasgow, Scotland

Neil McDonnell
Neil.McDonnell@glasgow.ac.uk
University of Glasgow
Glasgow, Scotland

Julie R. Williamson
Julie.Williamson@glasgow.ac.uk
University of Glasgow
Glasgow, Scotland

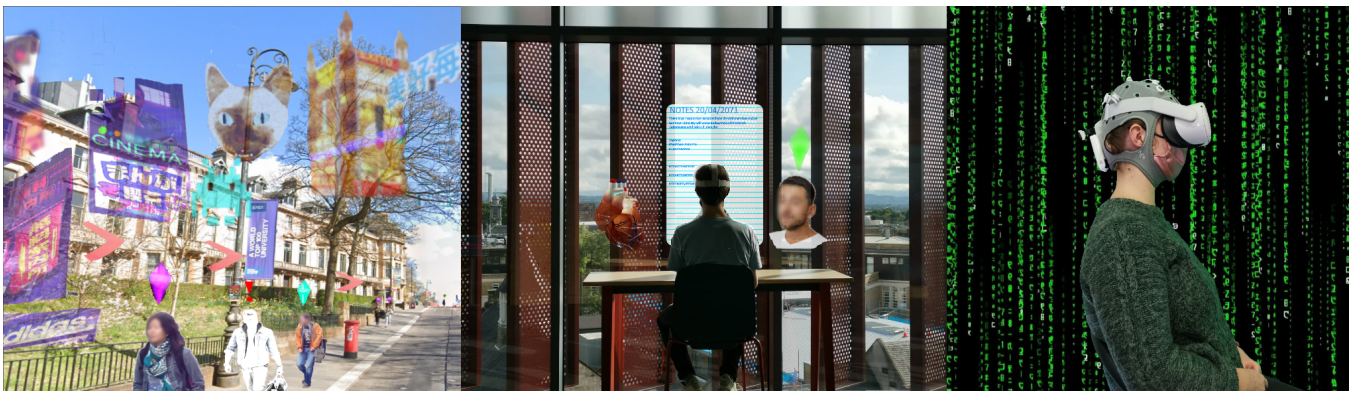

Figure 1: Envisioning the possible futures of XR technologies through design fictions. In outdoor (left) and indoor (middle) public settings augmenting the real world, and in private settings (right) replacing the world altogether virtually.

ABSTRACT

Is our future heading towards enhancing the human experience with computer-mediated reality? Immersive technology is unique, existing between the world and our senses, letting users traverse wholly virtual environments (i.e. distant places or fantasy worlds) or augment the real world with virtual objects, and any mix of virtuality-reality in-between. This paper explores the philosophical and social ramifications of ubiquitous immersive technology, envisioning a relatively near-future where mainstream technology has been replaced and a dystopian far-future wherein individuals may choose to abandon reality in favour of virtual worlds. Creating design fictions as thought experiments, we explore the open challenges of possible futures in XR, researching tomorrow's technologies today.

KEYWORDS

XR, Design Fiction as Thought Experiment, Possible Futures, Ubiquitous Computing.

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1 INTRODUCTION

We are accelerating towards a possible future where "always-on" immersive devices continuously augment human experience in everyday life, giving people the power to control their reality at will. Immersive devices designed for always-on interaction, including augmented, mixed, and virtual realities (together called XR), will fundamentally change how we experience our lives, give us more control and agency over our experiences, and augment and extend our human capabilities. The paper envisions a timeline where head-mounted displays (HMDs) tend towards moving dynamically along Milgram and Kishino's Reality-Virtuality (RV) Continuum (see Fig 2) [41]. Able to transition freely between realities (AR,MR,VR) in response to the real world and user preference. Exploring trajectories towards this possible future can provide insights into how we design immersive experiences, help us understand how XR will change our memories, and expose open challenges if we follow this path.

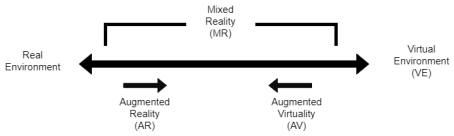


Figure 2: The Reality-Virtuality (RV) Continuum [41].

Salovaara et al. highlight an insurmountable flaw in current HCI evaluation methodology: due to the present-future gap one can

never truly know how a prototype will be used in real-world settings outside of evaluation [29]. While possible to evaluate remotely in the present-day [25, 39], this uncertainty grows as the timescale increases, until speculation becomes less meaningful. However, with sufficient staging (narrative) and implementation (prototyping) these techniques can be used to identify and avoid undesirable futures [36]. Design fictions, where fictitious worlds are presented with prototypes or well-crafted narrative [14, 23], are key in discerning open challenges that could arise from future technologies (in this case ubiquitous XR). Our paper responds to these works, with the addition of applied philosophy [4–6] in order to highlight potentially dystopian pathways, pursuing those that enhance the human experience favourably through design fictions as thought experiments.

Perhaps most pressing is how frequent use of such a personal and involved technology will affect society and individuals' mental health and well-being. Present-day immersive tech already overrides our senses, stimulating the same areas of the brain as in observing reality [22]. How these computer-mediated experiences are interpreted by our minds requires far more extensive study. What is clear however, is that within virtual environments (VEs) there exists a clear sense of presence. Just as in VR video-games [40], if not more so, users will remember interactions in XR neurologically as if they happened in real-life [3]. Increasingly so as future advancements are made in displays, haptics and brain-computer interfaces (BCIs). As immersive technology continues to step towards mainstream it becomes important to reflect on the ethics and implications of such devices; namely the potential for misrepresentation [2] and abuse [15]. By highlighting current trends and scandals in modern technologies, imagining these carried over into ubiquitous XR, we hope to spark discussion on how to best design immersive experiences of the future.

2 CASE STUDIES

We present a series of case studies that speculate farther into the future until virtuality surpasses reality:

(1) **NEAR FUTURE** Walking in a crowded outdoor public setting, such as a pavement or park, littered with AR advertisements, safety markings and wearable digital cosmetics visible to both the user and those in the vicinity that have "adopted" the technology.
(2) **DISTANT FUTURE** Productivity in public study spaces, such as a library or café, staging an educational scenario assisted with the use of MR. This case study envisions the perfect learning tool, utilising weightless portable displays and a one-on-one call with an expert in the field.
(3) **FAR-DISTANT FUTURE** Immersing oneself in a wholly VE in place of entertainment; or in the far-future even replacing life. This case study asks the participant to suspend their disbelief, imagining they are using a BCI that can precisely alter their memory and senses on a biological level.

As the case studies progress, we will introduce theorised near-to-far future technologies mocked with present-day devices: AR glasses, MR contact lenses and a BCI. The narrative is held together by a virtual assistant (VA) who too progresses (see Fig 3), evolving from a simple voice assistant into a human-centred artificial intelligence (AI).

Figure 3: Low-fidelity sketches for the design of the VA: upgrading from a simple 2D outline (left), to a 3D avatar (middle) until the experience is indistinguishable from speaking to a real person (right).

2.1 Changing Reality: CITIES SATURATED IN MEDIA

(a) Low-fidelity sketches

(b) Concept art

Figure 4: Rough sketches (a) and concept art (b) envisioning a near-future where ubiquitous AR glasses facilitate a shared AR world existing over our own, allowing users to see virtual displays, advertisements and wearable cosmetics.

Imagine the year 2030. You are commuting to work using your smart glasses. The glasses' on-board VA automatically syncs to your calendar, calculating the most efficient route to your destination. A heads-up display (HUD) presents this to you as well as the time, your

emails, and voice messages. All around you are virtual advertisements and public displays, reacting to the environment in real-time, moving out of the user's vision depending on obstacles and other commuters. Other early adopters stand out to you, with customisable digital cosmetics floating above their heads, often displaying chosen aspects of their personal identity: from as personal as gender, sexuality, or politics, to as simple as music taste or favourite colour.You notice a person completely obscured virtually, rendering them unidentifiable. You immediately recognise this as someone you have "blocked" and adjust your route accordingly, intent on avoiding the encounter.

Inspired by Keiichi Matsuda's concept film "Hyper-Reality" [1], the first section of the study envisions a near future where AR glasses are ubiquitous and sophisticated enough to track and filter elements of reality, including people, populating cities with virtual advertisements and public displays. Practical examples of person-filtering (i.e. 'blocking'), produced with machine-learning trained footage, are already possible [2]. While most conceptions of the "metaverse" envision a shared VR space, this study chooses to focus on an AR metaverse overlaying on the existing world as a framework for interactions (see Fig 4). As constant advancements are made in object recognition and spatial mapping we may soon see a world where our physical and virtual realities are merged in our day to day lives. The aim of this section of the study is to make participants question whether they are comfortable using an always-on device to inform their everyday choices and change how they perceive the world.

So how will this portal into an otherwise invisible world, much like our own intangible world wide web, affect our behaviour in real-world settings? Do these virtual objects tied to the real world, appearing unlike anything seen in nature (i.e. defying physics and exposing others personal information), present a unique threat to our autonomous choices and personal safety? Such advertisements have increased potential to subliminally influence the user just as current technologies do today (i.e. cookie pop-us, personalised ads and automatic mailing lists), changing the users choice architecture and political ideals unbeknown to themselves [32]. The 2016 Cambridge Analytica scandal saw personality modelling at scale [3], showing social-media users advertisements dependant on personality traits to sway their opinions in the upcoming US election. If no safeguards are put in place to prevent future uses of such invasive and influencing technologies, the average person may find themselves acting on auto-pilot [24], unable to resist the influences of highly personalised media, advertisements and news sources that by design confirm their own beliefs.

As the success of Niantic's *Pokémon GO* (a free-to-play location-based game where players capture and battle virtual monsters) has demonstrated, linking digital interactions to real-world locations can have unforeseen consequences to do with human mobility and safety [10]. Such technologies must be responsibly designed so experiences do not endanger the user. Additionally, will introducing social-media inspired functionality into real-world settings bring with it more emphasised modern-day problems of the platform (i.e. fake news, cyber-bullying and hate crime)? Imagine personalised advertisements, news and hateful messages stalking you everywhere you go, or people infiltrating real-world spaces intended for marginalised groups through digital deception. An entirely new category of cyber-crime, requiring law enforcement to adapt and individuals to consider how much information they are comfortable presenting readily to the world at a glance. This section of the study extrapolates certain trends and scandals in Web 2.0 technologies, namely individuals making their personal information and aspects of their core identity available online [38]. In a world of ubiquitous XR this information could be available to anyone within eyesight, potentially putting users at risk of manipulation and harm.

Of course at this stage in the fictitious timeline the user still has the option of removing the glasses (and opting out from recognition), however, as the technology is integrated into public displays and services they may be forced to use the device. Else risking loss of access to basic services such as public transport or online booking systems, already seen as businesses tend towards maximising profits and reducing staff. While there exists research on these topics [13, 21], none to our knowledge explore the ramifications of these technologies for public settings, social situations and personal autonomy. We ask the participant and reader to take these ideas further: exploring a thought experiment titled *Google Glass 2025*. Unlike in our timeline these glasses have perfect object recognition, slightly altering how the user sees real-world objects, for instance by increasing the saturation (in terms of colour levels) of certain products or people. How would one possibly combat against such subtle attention-manipulation? More importantly, what changes need to be made to stop this envisioned world: where the media we consume, our personal beliefs and waking experiences, even the people we choose to spend our lives with, could ultimately be decided by machines [31]?

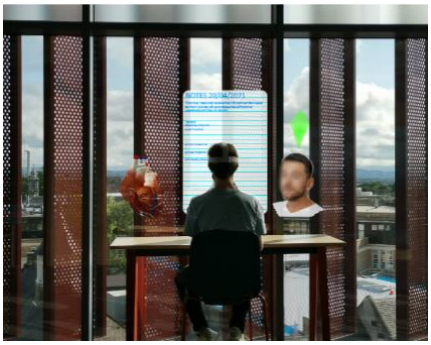
2.2 Blending Reality: THE DIGITAL DIVIDE

Imagine a distant future where the modern computer has been replaced by contact-lenses that can overlay information directly onto reality. You sit down in your office. Your device scans your environment and populates it with your usual work-space: three large screens, your calendar, and a virtual keyboard. Your VA narrates incoming notifications from colleagues and fetches information on user requests. You can adjust your proportion of reality to virtuality manually, maximising productivity by eliminating real-world distractions. Unfortunately, you've hit a roadblock and must confer with a colleague for assistance. You give them a message explaining the situation, not expecting an answer at such short notice. To your surprise, the colleague answers back promptly, requesting to enter your environment virtually to give hands-on assistance before they clock-off for the day.

In 1965 Sutherland envisioned an "Ultimate Display", one which could overlay computer graphics over one's own sight. He theorised the benefits of such a technology for educational purposes; aiding in the learning of aspects of nature humans have not evolved

[1] https://www.youtube.com/watch?v=YJg02ivYzSs
[2] https://www.youtube.com/watch?v=VqjLk8wzLv0
[3] https://www.nytimes.com/2018/04/04/us/politics/cambridge-analytica-scandal-fallout.html

(a) Low-fidelity sketches



(b) Concept art

Figure 5: Rough sketches (a) and concept art (b) envisioning a distant-future where ubiquitous MR contact lenses allow the average person to work and collaborate from any location using virtual displays and periphery, without the need for physical equipment - adapting automatically to their real world setting.

to see or intuitively understand [35]. Nowadays advancements in computer vision have allowed real-time hand-tracking for HMDs [16], utilising Augmented Virtuality (AV) [41], enhancing the virtual world with elements of reality. Users can now move and rotate virtual objects by hand without the need for a controller, able to view in-detail phenomena outwith human perception. Introducing information into a human environment, rather than having a human fumble through information on a computer environment [37].

This section of the study envisions refined versions of modern-day XR technologies (see Fig 5) for communication and productivity (i.e. Meta's Horizon Worlds and Infinite Office [4]), where Web 3.0 technologies have fully established themselves. While functional, present-day applications are not quite ready for prolonged use, owing to form factor and fatigue caused by in-air gestures [18]. In our fictitious timeline these difficulties have been smoothed out over the next 25 years. Now as small as a pair of contact lenses, with interactions designed to minimise fatigue and take into account human limitations in regards to precise gestures in 3D space [26].

[4] https://www.oculus.com/facebook-horizon/?locale=en_GB

Advances in hand and eye-tracking algorithms have also surpassed their modern-day limitations [16], supporting hand occlusion, hand-object interactions and understanding user-intention in real-time. Users can now bring about a powerful machine in everyday life (with as many displays as they require) and a guaranteed productive space, through person-filtering and noise-cancellation.

Compared to the prior case study users are now free to choose their reality, blending virtual elements with the real-world to assist in their work. As before users can choose to obscure nearby people or their surroundings altogether in an effort to increase focus. There are already working prototypes of technologies to recognise and alter aspects of our environments in real-time [11], as well as altering the orientation of virtual displays to assist user comfort and ergonomics [6]. Frameworks for approaches to transition between discrete mixes of RV [28, 41] exist but are limited by current display technologies. What is not certain is how to introduce these immersive and reality-filtering experiences into public settings. How would a bystander interact with the user if they are rendered invisible and inaudible by the device? Similar issues deter present-day immersive experiences in public spaces, as while wearing a HMD, bystanders are uncertain of the intention of the user's actions and are unable to see what their behaviour (i.e. in-air gestures, posture or gaze) is in relation to [12]. Additionally, by obscuring reality the user naturally puts themselves at risk, blind and deaf to their immediate surroundings; impaired when it comes to dealing with real-world social situations or dangers.

Recent research has demonstrated that while not going as far as enhancing quality of knowledge, AR-supported learning does improve the efficiency at which one learns (aiding comprehension with interactive 3D virtual objects and reducing time needed for setting up physical equipment) [1, 20]. So how will this new generation, unencumbered from physical displays and two-dimensional learning, fare in this new world centred around immersive skills? Will these advancements breed a brighter generation or one arrogant with the wealth of information at their fingertips? In their paper, "Googled Assertion", Carter et al. discuss literature on *extended cognition*: exploring the differences between biological memory and notepad-assisted or technology-assisted examples of extended memory [4]. Citing previous work they present Otto [8], an Alzheimer patient who uses a notepad to assist his memory in day-to-day life, and John who uses his smartphone to deceive his friends during a dinner party; appearing more knowledgeable on a topic than he actually is. While Otto adheres to the requirements to be considered extended cognition, due to the constant feedback loop between himself and the notepad, John's action is little more than a bluff.

In this paper we present a third character using the aforementioned XR contact-lenses on a daily basis. The device continuously monitors their world, including listening in to conversations and presenting relevant information through feedback loops, allowing them to discretely deceive others into thinking they are knowledgeable on topics they are not. Unlike John, who on probing would be exposed as a fraud, future XR devices could rapidly generate rebuttals unknown to other parties. As devices like this integrate themselves into the more personal aspects of our lives, able to direct

the flow of conversation, how will we be able to tell the difference between the truth and augmented-vision assisted deceptions [30]? Having used the technology for most of their adult-life will our character be overconfident in their intellect, or riddled with impostor syndrome? Will individuals who choose to rely on biological memory alone be ignored by workplaces, seen as inferior? Inviting technology into our senses is a very personal choice, will this choice be forced upon us as workplaces demand immersive skills and extended memory as the standard?

2.3 Exceeding Reality: EXPERIENCE MACHINES

(a) Low-fidelity sketches

(b) Concept art

Figure 6: Rough sketches (a) and concept art (b) envisioning a far-future where BCIs can affect our memories and senses indistinguishably from real-world stimuli. People now spend their time exploring virtual worlds or celebrity experiences.

Imagine a far-future wherein the present-day mysteries of the human mind are made trivial. Computers interface directly with the brain, allowing for instantaneous information retrieval; downloaded straight to memory. With advancements in artificial intelligence (AI) and robotics most are unemployed, unequipped to deal with the competition, leaving them free to explore vast online virtual worlds and communities. People now choose to spend more time in virtual worlds than reality, some going as far as purchasing pre-programmed "perfect" experiences free of worldly stresses. Your VA, now indistinguishable from a living human in appearance and behaviour, guides you through an extensive catalogue of virtual worlds and experiences.

If today's achievements in BCIs already seem unbelievable, like controlling drones with our minds [7], then it stands to reason that breakthroughs in the future could be truly life-changing. Our human capabilities may be augmented, able to interact with machines with a mere thought. In the previous case study we saw Otto, if born in this envisioned future his Alzheimer's could be cured, his biological memory assisted by computers in real-time. Amputees could be given prosthesis that function just like a normal limb, reading signals directly from the brain. Perhaps this could lead to some sort of telepathic hive-mind facilitated by BCIs, developing a better understanding of ourselves in regards to others, this technology could literally let us live life through another person's lens. While this concept could be a paper in itself, we choose to narrow our focus: questioning whether in a world where you can experience anything you want (i.e. virtual worlds and experiences), would the real world still have any appeal?

To a hedonistic utilitarian such a scenario would be delightful, able to satisfy their every desire virtually (identical to their body and memories to real-world experiences), shutting off from reality altogether. How is this different to people glued to their screens today? Choosing to ignore their immediate surroundings and focus on a more appealing intangible virtual world (i.e. social-media, video-games and television). Our fictitious timeline sees these addictive elements of Web 2.0 amplified, with computers now having Nozickian Experience Machine capabilities: wholly able to convince the user that the reality presented by the device is real, even going so far as erasing their memory of using the device in the first place [5, 6, 27]. Such a world highlights the need for responsible immersion and a greater understanding of how the brain interprets virtual events, else risking fragmentation of society due to individualised realities.

Imagine a shared virtual "dream-world" wherein sufferers of brain injuries, or other impairments, could live a life unburdened by their physical conditions. Before death, human consciousness could be downloaded and integrated into this virtual world, making the average person immortal. We must again consider whether this infringes on our autonomous choices. Being placed in a virtual world indistinguishable from reality, perhaps with no escape, against your consent is a truly terrifying thought. Else by communication via BCIs it is uncertain how these incapacitated and dying individuals could give their informed consent to such an act. If the choice to do so is not voluntary, then it is not autonomous [9].

What are the implications for this sort of technology in everyday life? To explore this further we introduce a second thought experiment: Betty exists in the far-distant future, using a BCI that through artificial-intelligence (i.e. monitoring habits, listening to conversations) now knows users better than they know themselves. Having monitored Betty for many years the device learns that she

has an intense hatred towards a certain group of people. The device increasingly begins to associate this group of people with bad connotations, much like the user. One day Betty is looking out her window, she sees a man in a football strip (associated with this group) brutally assaulting and murdering another man. She immediately contacts the authorities, describing the details of the incident. But now Betty must question the validity of her memory, was the murderer really of that group? Or through feedback loops had her device changed her perceptions of the event due to her existing bias? If this reality-warping technology becomes so sophisticated we may see a world where we must constantly question our senses.

3 OPEN CHALLENGES FOR POSSIBLE FUTURES OF UBIQUITOUS XR

These case studies expose open challenges in ubiquitous XR. Some of these issues have long been recognised, and now come to the forefront as ubiquitous XR becomes technically feasible in real world settings:

(1) **Mediated Perception:**
Understanding how immersive experiences, including reality-virtuality transitions, are perceived and woven into memory.

(2) **Reality and Virtuality Anchors:**
Future immersive technologies present unprecedented challenges for ethics. If digital immersion is to become indistinguishable from our physical senses, there is a desperate need for elements that help us discern between reality and virtuality.

(3) **Value of Virtual Experiences:**
Whether virtual experiences have the same intrinsic value as real ones or not. Are they merely a tool?

(4) **Immersive Skills and Digital Exclusion:**
Our envisioned future trend, seeing those that do not adapt to immersive technologies as disadvantaged - losing access to society in fundamental ways.

3.1 Mediated Perception

XR is distinct from other personal devices because unlike most devices that exist *within* our world, XR sits *between* our senses and the world. XR will change how we remember our lives. Research demonstrates that experiences in virtual environments are remembered using the same neural structures as physical environments [22] and social interactions that occur in virtual environments are remembered and described as places where users might experience something together [3]. Immersive systems have the potential to manipulate perceptions and change the way that experiences are remembered. For example, imagine an XR application that allows a distributed group of friends to enjoy a dinner party as if they were physically together. What kind of visual, aural, tactile, and spatial representations would be needed for this experience to be remembered as if the friends were "really together" in one place? What aspects of the virtual experience would break the illusion and anchor the user in reality? How do users differentiate and move between their immediate surroundings and this virtual context?

As immersive technologies are released and become ubiquitous, it becomes increasingly important to study the long-term effects of virtual memories and experiences. Previous research has highlighted the uncomfortable sensation of re-acclimatising to reality after removing a HMD [19], as well as *Alternate World Syndrome* where expectations of virtual worlds are mistakenly placed on the real one [17]. Are such findings the tip of the iceberg? It may be that our brains constantly war to make sense of digital media in relation to real-world experiences. Despite being virtual experiences, immersive technology can have serious real-world consequences. Especially as technologies improve (from HMDs, to contact-lenses to BCIs) and become more widely used, it is important to consider how best to design virtual experiences for our long-term health and well-being.

3.2 Reality and Virtuality Anchors

Immersive content that passes the "Ultimate Display Test" [34], where virtual content is indistinguishable from physical content, could change the philosophical foundations for realism and causation. Shapiro and McDonald describe the philosophical challenges of hyper-realistic immersive content and how this will change judgements about reality [33]. Effective reality judgements and reality anchors [17] will be crucial to creating auditable immersive experiences. In our design fiction the VA serves as a virtuality anchor, holographic in nature and consisting of a floating head to clearly show the user that it is not a product of reality. But as AI and hyper-realism become achievable, and the VA is now indistinguishable from a living human, how can we design experiences so that users can tell the difference between real and virtual content? As these advances are made, we will have to be able to produce virtual objects that at a glance can be identified as virtual - a form of "hyper-irrealism". Else we risk user safety and confusion, opening the door to the creation of dangerous and misleading immersive experiences - especially as these experiences become common-place in public settings.

3.3 Value of Virtual Experiences

Being a subjective matter, it is hard to define the value of virtual experiences. In comparison to "real" experiences, these virtual experiences can aid in comprehension (i.e. through 3D visualisation [20]) and provide the same emotional response as in real-world situations. A good comparison would be playing a game in a physical setting, opposed to playing a team-based video-game: while not in the same location users will experience the same joys and woes, they will learn similar lessons to those they would in "real-life". It stands to reason that the subjective value of these experiences will increase with advancements in technology, the value given by a modern-day HMD would be almost incomparable to a BCI. Will there come a point when virtual experiences are actually valued more than "real" ones?

Virtual and augmented experiences can definitely add value to

real-life situations. For instance users could enter a relaxing environment for stress-relief, set AR reminders and directions to alleviate their anxiety in everyday life, or in some cases users could prepare for the day: living out an experience virtually before acting it out in the real-world (i.e. VR exposure therapy to combat agoraphobia). This could perhaps offer an alternative to drugs which due to addictive properties can have the risk of causing more harm than good.

However, just as with any tool, experience design and how users choose to interact with the device will be the primary factors that add or detract value from the experience. . Our envisioned far-distant future BCI would be capable of hyper-realistic experiences far more appealing than our everyday lives. What value this brings is ultimately decided by the individual, even if that leads the user to prioritise this new "perfect" reality over their own.

3.4 Immersive Skills and Digital Exclusion

Just as many struggle to adapt to a world with an increasing need for computer literacy, will we one day be required to adopt immersive skills in order to interact with society? In our design fiction we explored how in the future lacking an XR device may mean losing access to social and public services, access to work and at the worst-case being uncertain of our very memories. As these case studies progress into the future, seeing the release of BCIs, will people even want access to society or will they be content with the infinite experiences and virtual worlds at their disposal?

As opposed to technologies that exist within our world (i.e. mobile phones), XR exists between the world and our senses. Inviting such technology into this space, especially for everyday life, is a personal decision. We must ensure that in the future being a member of society holds no requirements to use potentially harmful and invasive technology.

4 CONCLUSION

Immersive technology is moving towards a possible future where "always-on" immersive devices continuously augment human experience in everyday life. In this paper we explored this possible future through design fictions as thought experiments, envisioning three distinct futures (approximately 10, 25 and 100 years forward). Design fictions give us the tools to explore potentially dystopian pathways by creating fictitious worlds. For all the issues exposed by these case studies, threads of these exist in our current technologies and society, only by acknowledging these issues can we design to prevent them. We hope this design fiction stimulates discussion on the topic and inspires further work, particularly to do with interdisciplinary collaboration as advances in technology continue to prompt discussion on theoretical philosophy.

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