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The Aftereffects of Virtual Reality: A Narrative Review

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Abstract

Virtual Reality (VR) has advanced considerably in recent years, with improved headset technology, more immersive games and applications, and wide-ranging uses across multiple industries. However, despite these advancements, negative impacts on the user remain, including cybersickness and aftereffects. While cybersickness has received considerable attention in the literature, investigations of aftereffects are more disparate. In this narrative review, I provide an overview of research in the field of aftereffects. In particular, I focus on sensorimotor, oculomotor, and cognitive aftereffects, evaluating the present evidence in each of these domains. Sensorimotor aftereffects include proprioceptive and coordination errors and postural instability. Oculomotor effects include disruptions in accommodation and convergence, as well as subjective symptoms such as blurred vision and sore eyes. Cognitive aftereffects include disrupted reaction times, although evidence for impacts across other functions is sparse. I also discuss potential mechanisms, such as sensory conflicts, technological factors, and cybersickness, and provide suggestions for future research in this field. Overall, understanding the extent and cause of VR aftereffects is important to ensure the applicability of this useful technology.

Key words: Virtual Reality, Augmented Reality, Aftereffects, Cybersickness, Multisensory Integration

Statements and Declarations

The author confirms no financial or non-financial interests directly or indirectly relating to this work.

The use of Virtual Reality (VR) has boomed in recent years, with VR applications spanning across entertainment (Bruni & Galvagno, 2025; Deepanshi et al., 2025), teaching and training (Alaker et al., 2016), research (Doeller et al., 2010; Peck et al., 2013; Thür et al., 2019), and medicine and rehabilitation (Cameirão et al., 2012; Levit et al., 2025). While VR has considerable application across many areas, negative impacts of VR on the user remain. Cybersickness (a form of motion sickness) can cause considerable nausea and disorientation in VR users, limiting the utility of VR (Caserman et al., 2021; Dużmańska et al., 2018; Gallagher & Ferrè, 2018; Palmisano et al., 2017; Rebenitsch & Owen, 2016), although there may be significant individual differences in those who are impacted (Golding, 2006; Munafo et al., 2017). The precise causes of cybersickness are still debated, with several theories proposed to explain the mechanism underlying motion sickness in general. Sensory conflict theories posit that cybersickness arises due to conflicts between senses signalling self-motion , conflicts in expected and actual subjective vertical, and/or when predicted and actual sensory outcomes do not match (Bles et al., 1998; Bos et al., 2008; Gallagher & Ferrè, 2018; Khalid et al., 2011; Reason, 1978). Such conflicts may be driven by technological factors such as lag or the design of the virtual environment, the experience of vection (an illusion of self-motion), or in multisensory integration and reweighting strategies, with some evidence suggesting more severe symptoms with greater levels of conflict (Biswas et al., 2024; Chung & Barnett-Cowan, 2023; Hettinger & Riccio, 1992; Keshavarz et al., 2011; Teixeira et al., 2022). Alternatively, postural instability theory proposes that cybersickness might arise due to challenges with postural stability, where symptoms are provoked in situations where strategies to stabilise posture have not been learned (Stoffregen et al., 2000; Stoffregen & Riccio, 1991). Accordingly, those with greater instability when immersed in a virtual environment are more likely to experience symptoms of cybersickness (Smart et al., 2002; Stoffregen & Smart, 1998). Potential solutions to cybersickness range from simple repeated exposure (“gaining your VR legs”) (Dużmańska et al., 2018; Hill & Howarth, 2000; Howarth & Hodder, 2008; Palmisano & Constable, 2022; Risi & Palmisano, 2019) to application of vestibular stimulation (Cevette et al., 2012; Reed-Jones et al., 2007; Weech et al., 2020), although at present cybersickness remains a barrier for VR uptake.

While much ongoing research is dedicated to understanding and solving the issue of cybersickness, far less attention has been given to negative impacts of VR that persist after the headset is removed. Pioneering research by Stanney and others in the late 1990s first identified proprioceptive and postural aftereffects of VR exposure, along with lingering cybersickness symptoms persistent for hours after VR exposure (Stanney et al., 1999; Stanney & Kennedy, 1998). Since this early research, further aftereffects have been found including perturbations to proprioceptive coordination (Champney et al., 2007; Pettijohn et al., 2018; Stanney et al., 1999), altered reaction times (Mittelstaedt et al., 2019; Nalivaiko et al., 2015; Szpak et al., 2019), and depersonalisation/derealisation (Aardema et al., 2010; Peckmann et al., 2022), among many more. Thus, despite advancements in HMD technology since the first pioneering aftereffects research, aftereffects may still be prevalent.

A complete understanding of which domains are affected by VR, who is impacted most by aftereffects, how long they last, and consideration around possible mechanisms driving them is necessary to ensure full applicability and safety of VR. In this narrative review, I provide an update of the current literature regarding VR-induced aftereffects, and outline gaps in our knowledge requiring further attention. While Cybersickness is a related topic, it will not be covered in this review – readers are instead directed towards articles by Caserman et al. (2021), Lawson and Stanney (2021), and Rebenitsch and Owen (2016) for in-depth analyses of this topic. In addition, attention is paid only to studies which investigate *unintended* aftereffects of VR exposure, as opposed to studies which deliberately induce aftereffects to investigate other aspects of sensorimotor or perceptual functioning (e.g., Culicetto et al., 2024; Wähnert & Gerhards, 2022; Wähnert & Schäfer, 2024). In particular, I review aftereffects across sensorimotor, oculomotor, and cognitive domains, and speculate on potential explanations for aftereffects reported in the literature. I conclude by providing suggestions for future avenues for research to further elucidate the potential consequences of VR immersion.

Review method

Papers were found by using search terms "VIRTUAL REALITY", "AUGMENTED REALITY", "EXTENDED REALITY" and "AFTER-EFFECT" or "AFTEREFFECT" in Google Scholar, Web of Science, and PubMed search engines from January 2024 to June 2025, in addition to papers already known to the author. Studies cited within these papers were also included where relevant. Papers were included in the narrative review if they discussed changes to sensorimotor, oculomotor, cognitive or other functions following exposure to VR/AR, but were excluded if they were designed to specifically induce changes to these functions (for example, VR training or VR prism adaptation studies). Studies which focused only on cybersickness were excluded. No exclusions were applied on the basis of publication date or VR type.

Sensorimotor

Sensorimotor consequences of VR exposure include changes in proprioception, coordination, and postural stability. Many early studies focused on pointing tasks, investigating participants' ability to point at visible or remembered targets before and after exposure to virtual environments (Biocca & Rolland, 1998; Champney et al., 2007; Harm et al., 2008; Stanney et al., 1999; Stanney & Kennedy, 1997). However, little attention has been paid to sensorimotor disruptions using modern VR headsets, potentially due to changes in HMD and controller technology.

Proprioception and Coordination

Stanney and Kennedy (1997) and Stanney et al. (1999) used pointing tests to investigate proprioceptive recalibration following short (~30 minute) exposures to VR with early Head-Mounted Displays (HMDs). Participants were shown targets on a digitising tablet and were asked to touch the target location with a stylus attached to their finger. The pointing task was completed with no delay or with a short delay between target presentation and pointing movements. The task was repeated with eyes open and closed before and after VR exposure. In both studies, small (~2-6mm) but significant errors in pointing performances were found when the eyes were closed, but no differences were found in pointing accuracy with eyes open. There was also no effect of delay. Importantly, neither study found evidence for a correlation between pointing errors and cybersickness, suggesting that these two phenomena may be influenced by separate mechanisms. Similar findings of pointing error were reported by Champney et al. (2007), who investigated whether 'readaptation strategies' could be used to reduced aftereffects caused by exposure to immersive virtual reality. Participants completed several tasks, such as object manipulation and reaction time tasks, while navigating a VR maze. Measures of hand-eye coordination and postural stability (discussed below) were taken via pointing tasks before and immediately after, and every 15 minutes up to 1 hour post-exposure. Some participants were given exercises designed to overcome aftereffects, including completion of a pegboard task to reduce proprioceptive coordination disruptions and rail walking to reduce postural instability. Approximately 60% of participants had significant pointing errors immediately after VR exposure, with an average increase of 99.88% but with significant variation (0.02%-946.32%). Alarmingly, those participants who displayed pointing errors post-VR had not returned to their baseline level of performance even 1 hour after exposure. However, participants who had engaged in the pegboard readaptation strategy had lower errors at 15-minutes post-exposure versus the control group and rail walking group, suggesting that strategies to prevent coordination aftereffects may promote at least some level of recovery.

Several other studies have found similar results using different VR tasks, devices, and measures. Harm et al. (2008) investigated how much time it took for proprioceptive coordination to return to baseline following exposure to VR presented in an immersive dome. Similar to previous studies, the VR task involved participants moving objects from one side of the virtual room to the other, but presented in a 12-foot spherical dome, rather than within a HMD. Participants displayed significant increases in horizontal and vertical pointing error (~25mm relative to baseline) immediately following VR exposure, with return to baseline by 6 hours post-exposure. Interestingly, similar pointing errors were reported by Biocca and Rolland (1998) following use of a 'see-through' HMD. Like many modern mixed-reality HMDs, this device used cameras to project the view of the real room to participants, rather than immersing them in a fully virtual world. These cameras rendered images that were forwards and upwards of the real eye, displacing visual information downwards and inwards relative to vision without the HMD. Participants completed several measures of pointing accuracy before, during, and after exposure to the HMD or a control device. During HMD use, pointing errors in the Z and Y axes increased relative to baseline and to the control device, with maximum errors of 65mm and 27mm respectively. After removing the HMD, participants showed smaller, but significant pointing errors in the opposite direction (~35mm Z axis error, ~10mm Y axis error). However, it is unclear for how long these pointing errors persisted, and whether modern mixed-reality HMDs will induce similar effects.

Together, these studies provided insights into pointing error following VR exposure, suggesting disruptions of hand-eye coordination following VR exposure. However, it is important to note the significant differences in HMD and controller type in comparison to modern HMDs. In particular, many headsets used in these previous studies had a narrow field of view (50° in Stanney et al., 1999; Stanney & Kennedy, 1997 versus 110° in a modern Meta Quest 3, for example), and participants were often required to navigate the virtual environment using a computer mouse versus touch controllers used today. Given our previous understanding of sensorimotor adaptation (Bastian, 2008; Wähnert & Gerhards, 2022), it is perhaps unsurprising that mixed-reality headsets, with displaced cameras projecting views of the real world to users, might impact sensorimotor coordination. While many studies use such displacement to investigate important phenomena (Cho et al., 2020; Ueyama & Harada, 2022), it is important to consider potential impacts of these displacements on real-world coordination when they are unintended. Lee and Park (2020) found little impact of displacements up to 50mm in a see-through HMD on several sensorimotor coordination tasks, while displacements above 200mm led to reduced performance which did not recover even after 3 days of repeated exposure. Such findings suggest that small displacements of cameras in mixed-reality HMDs may be tolerable, while larger displacements will continue to induce aftereffects over longer periods of time which do not reduce with repeated exposure. However, such findings do not fully account for the proprioceptive disruptions anecdotally reported by users of modern VR headsets (Porter II & Robb, 2022). For example, VR users have reported feeling as if their hands 'lag' behind their actual motion, or perceiving their hands to be further away from the body than their actual location, resulting in problems when reaching to grasp objects (Porter II & Robb, 2022). Ultimately, studies investigating full-immersion VR and mixed reality in modern headsets are necessary to continue to build our understanding of HMD use on proprioceptive coordination.

Postural Stability

In addition to pointing tasks, many studies have established that postural stability is also altered by VR exposure (Akizuki et al., 2005; Champney et al., 2007; Clark et al., 2021; Cobb, 1999; Horlings et al., 2009; Nishiike et al., 2013; Park & Lee, 2020; Pettijohn et al., 2018). During VR exposure itself, postural stability can decrease to a level comparable to the changes evident with eyes closed (Horlings et al., 2009). Such effects may persist on termination of exposure, although a full understanding of the magnitude and duration of these effects is lacking. For example, Cobb (1999) found that participants reported subjective symptoms of postural instability immediately post 20 minutes of VR exposure. They also found small (~20mm) but significant increases in sway after exposure to VR, but these impacts subsided by 10-minutes post-exposure. In contrast, Champney et al. (2007) found increases in front-back (mean = 72.69%) and side-to-side (mean = 85.25%) sway in approximately 50% of their sample, albeit with considerable variability (front-back: 0.07-872.67%, side-to-side: 0.04-799.61%). Moreover, performance did not return to baseline at 1 hour post-exposure, and readaptation strategies had little impact on reducing the instability. In contrast to these studies, however, some studies report limited impacts of VR exposure on postural stability. For example, Pettijohn et al. (2018) found reduced postural stability following 3x 10 minute exposures to a VR boat ride on a motion platform, but only when participants were not allowed to move their feet to compensate for the motion. It is possible, however, that the motion platform itself resulted in more postural perturbations than the VR simulation per se, and further work is necessary to understand the contribution of both to postural instability. Moreover, Tychsen and Foeller (2020) immersed young (4-10 years old) children in a VR flying game for 2x 30 minute sessions and measured postural stability through a modified Rhomberg test. Although a 9% reduction in postural stability was observed after the 60 minutes total VR exposure, this was not significantly different from baseline performance. It is important to consider whether these findings are specific to the child sample, or whether other factors such as the game type or HMD could influence results. Overall, the majority of postural instability studies typically focus on measuring sway before and immediately after VR exposure: future research would thus benefit from exploring the duration of these effects to reconcile these disparate findings.

Although more work is needed to establish the magnitude and duration of postural instability aftereffects, the causes for this instability have received some attention. Several VR environment and technological characteristics have been suggested to impact postural stability. Display lags in particular may impact stability post-exposure: Akizuki et al. (2005) found decreases in Rhomberg Ratio (the ratio of body sway path with eyes closed to eyes open) following 15 minutes of VR exposure, which worsened following shorter (3 minute) exposures with deliberately augmented display lags. This suggested that participants became less dependent on visual signals for postural control after VR exposure, with further downweighting when lags become more severe. Such display lags may relate to visuo-vestibular conflict, evidenced by increases in postural instability when conflicts are induced by displaying a moving a VR environment around a stationary VR user (Nishiike et al., 2013; Park & Lee, 2020). For example, sway velocity and sway length significantly increased following 15 minutes of exposure to a driving game in a PlayStation VR HMD, while no changes were found following exposure to a game with a fixed background using the same headset (Park & Lee, 2020). In such circumstances, vision signals that the user is traversing through the virtual environment, while the vestibular system indicates that they are stationary. Such conflicts are frequently associated with cybersickness (Gallagher & Ferrè, 2018; Khalid et al., 2011; Rebenitsch & Owen, 2016), but their relationship to aftereffects requires further exploration.

Summary

In sum, a range of studies suggest that VR can induce sensorimotor perturbances which persist following short exposures. Early research emphasized the impact of VR on proprioceptive coordination, with several studies reporting increased pointing errors after exposure. Similar findings have also been reported for see-through HMDs, which could suggest that mixed/augmented reality displays which use similar camera projections could have similar impacts. However, more research is necessary to investigate whether similar effects persist in modern HMDs, where fields-of-view, display lags, and controller types differ significantly from the devices used in these earlier studies. More recent evidence highlights the impact of VR on postural stability, although the magnitude and duration of such effects is debated. It is possible that postural instability results from characteristics of the VR environment/technology, with display lags and visuo-vestibular conflicts contributing to worsening impacts. Taken together, it is therefore possible for VR to significantly disrupt sensorimotor processing, with ongoing work necessary to clarify the mechanism and impact of these aftereffects.

Oculomotor and Visual Disturbances

Binocular vision

As well as sensorimotor effects, VR has the potential to cause oculomotor and visual disturbances. This is evidenced by VR users reporting blurred vision, sore eyes and perceptual alterations such as trouble judging object distances and alterations in their 3D perception (Hirzle et al., 2022; Porter II & Robb, 2022). Changes in depth perception specifically may be related to the way in which HMDs simulate depth. Under normal binocular viewing, two main processes allow the oculomotor system to maintain focus on objects at different depths. Vergence is the process by which the eyes move together to centre distant objects on the foveae. As objects move from far to near, the eyes converge or rotate inwards towards the nose. As objects move from near to far, the eyes diverge or rotate away from the nose. Accommodation is the movement of the ciliary muscles to adjust the shape of the lens, maintaining sharp focus throughout depth. Focusing on near objects contracts the ciliary muscles, thickening the lens and strongly refracting light to create a sharp image. By contrast, focusing on distant objects relaxes the ciliary muscles, thinning the lens and slightly refracting light to create sharp focus. In the real world, vergence and accommodation are tightly coupled to both maintain the position of the objects on the fovea and refract light to generate sharp representations on the retina. In VR, HMDs de-couple these reflexes by simulating depth through screens placed close to the eyes. Depth is simulated by altering the offset of virtual objects on screens presented to each eye, with greater offsets creating the illusion of further distance. Vergence is therefore based on the virtual depth of the object, with the eyes rotating as necessary to keep the virtual object centred on the fovea of each eye. However, as the HMD screens remain at a fixed distance to the eyes, accommodation is maintained based on the physical location of the screens and does not change regardless of the simulated depth of the virtual object. Accordingly, accommodation thus no longer works in tandem with vergence, generating a conflict between these two ocular functions. This vergence-accommodation conflict has the potential to alter oculomotor function beyond exposure to the VR environment.

A number of studies have found changes to vergence and accommodation following exposure to VR gaming, generally with increases to accommodation most commonly reported (Mohamed Elias et al., 2019; Munsamy et al., 2020; Szpak et al., 2019, 2020; Yoon et al., 2020, 2021). For example, Szpak et al. (2019) exposed participants to 30 minutes of a VR table tennis game via an HTC Vive HMD. The Royal Air Force near point rule was used to assess accommodation and convergence before and after VR exposure, and compared to a control group who "went about their daily activities" for 30 minutes. No changes in accommodation were found in the control group over time, nor between the control and VR group before VR exposure. However, significant increases in near point accommodation were found after versus before VR exposure in the VR group. No changes were found in convergence. Similar findings were reported in a later study by the same group (Szpak et al., 2020). Participants played Beat Sabre, an interactive game in which participants cut through blocks approaching them set to the rhythm of music, for 10 or 50 minutes via an HTC Vive, and accommodation and vergence were measured immediately and 40 minutes post exposure. Immediate changes in both accommodation and vergence were found, regardless of exposure duration, suggesting that exposure time has little influence on the severity of oculomotor changes. Importantly, however, both reflexes returned to baseline by the late measurement period, suggesting fast recovery.

Vestibulo-ocular reflex

As well as changes to accommodation and vergence, Di Girolamo and Pic (2001) reported changes in vestibulo-ocular reflex (VOR) gain following exposure to VR. The VOR is a reflex which stabilises gaze in response to head movements. Acceleration and rotation of the head is sensed via the vestibular labyrinths, which send counterrotation signals to the ocular muscles, maintaining gaze in space. In VR environments, it is possible for the VOR to become less effective if the virtual environment does not update perfectly in response to head movements. Participants played a VR game in which they had to climb over surfaces, navigating by aiming with gaze location and initiating virtual movements with a mouse. Following this exposure, VOR gain decreased significantly, suggesting that a de-coupling of VOR from the visual environment had taken place. However, it is important to note that this study used an older VR headset with a navigation strategy which differs markedly from modern headsets, and accordingly modern studies are necessary to investigate whether such changes to VOR gain are present today. Relatedly, I have previously reported changes in vestibular-evoked myogenic potentials (VEMPs; a vestibulo-spinal reflex elicited through sound-evoked otolith stimulation) and vestibular perception following short (~60s) exposures to visuo-vestibular conflicts in VR (Gallagher et al., 2019, 2020), with increased VEMP asymmetries and decreased vestibular perceptual sensitivity. Together with the findings of Di Girolamo and Pic (2001), such results suggest broad changes in vestibular functioning following visuo-vestibular conflict, although future research is needed to explore whether similar effects are present when using longer durations of exposure and more complex VR environments.

Relationship to cybersickness

It is possible that changes to oculomotor function are associated with increased symptoms of cybersickness during VR exposure. Szpak et al. (2019) reported a significant positive correlation between changes in accommodation and nausea, disorientation, and total cybersickness symptoms assessed through the Simulator Sickness Questionnaire (Kennedy et al., 1993). Similarly, Yoon et al. (2021) reported increases in dizziness, difficulty focusing, headaches, nausea and symptoms of dry eyes with changes in accommodation and convergence, further highlighting the association between subjective cybersickness symptoms and oculomotor changes. However, a number of other studies have found little impact of VR exposure on binocular vision, or on the association between oculomotor changes and subjective symptoms (Drouot et al., 2021; Ha et al., 2016; Turnbull & Phillips, 2017; Tychsen & Foeller, 2020). For example, Drouot et al. (2021) reported little change in oculomotor functioning after completing a construction task in augmented reality. However, participants still reported subjective symptoms of blurred vision, sore/aching eyes, headache and fatigue following AR exposure, suggesting that the coupling between these subjective symptoms and objective changes is less clear than previously reported. Moreover, several studies report little changes in binocular function in children and adolescents following various types of VR exposure, contrasting with findings reported above on adult samples (Ha et al., 2016; Turnbull & Phillips, 2017; Tychsen & Foeller, 2020).

There may be a number of reasons for these contrasting findings. While clear differences exist between studies using adult versus child samples, there may also be differences in the type of VR headset, environment, and interaction type which may also influence the results. For example, Szpak et al. (2019) and Szpak et al. (2020) used active VR games requiring participants to interact with an intense virtual environment, while Ha et al. (2016) required participants to passively watch movies presented on the headset, and Turnbull and Phillips (2017) and Tychsen and Foeller (2020) presented participants with less intense VR environments to minimise nausea. It may therefore be possible that the intensity and type of interaction have an influence on oculomotor consequences of VR exposure, but studies specifically designed to assess this idea have not yet been conducted.

Summary

Overall, there may be some limited effects of VR exposure on oculomotor functioning. The majority of studies have found small, but significant, impacts of HMD use on accommodation and (occasionally) vergence. These impacts do not appear to reach clinical thresholds, and some studies suggest that they recover quickly, although more evidence is needed to establish the full extent of these effects, particularly based on the type of VR scenario presented to participants. Subjective symptoms, such as blurred vision, headaches, and dizziness are also common, although the exact link between oculomotor changes and these subjective issues requires further investigation.

Cognitive

Reaction Time

In comparison to oculomotor and sensorimotor domains, cognitive VR-aftereffects have only just begun to garner attention. By far the most attention has been allocated to how VR impacts reaction time (RT). Many studies evaluate simple RT, how quickly a participant responds to a single stimulus, and choice RT, how quickly a participant responds to a stimulus which can appear in one of multiple locations. Initial research found an approximate 20-30ms increase in simple reaction time after 14 minutes of exposure to VR rollercoasters (Nalivaiko et al., 2015; Nesbitt et al., 2017). These initial findings used passive VR scenarios, where participants were not required to interact with the virtual environment. However, similar findings have been reported following exposure to active VR games (Mittelstaedt et al., 2019; Szpak et al., 2019, 2020). For example, Mittelstaedt et al. (2019) found significant increases in simple and choice RT following exposure to a cycling simulator presented on a HMD or large screen. Similarly, Szpak et al. (2019, 2020) evaluated whether choice RT decision times (how long it takes for a participant to notice a stimulus has appeared and release a button they had previously been holding down) or movement times (how long it takes for a participant to touch the target after releasing the button) were investigated by VR exposure. They found slower decision RTs immediately after VR exposure, but no change in movement RTs, suggesting that changes in RT may be specifically linked to cognitive, rather than motor, factors. In addition, RTs returned to baseline 40 minutes after exposure, suggesting relatively rapid recovery of these aftereffects.

While many studies have found an impact on RT, this has not been replicated in all studies. For example, Szpak et al. (2022) found no change in choice RT decision or movement speeds following 50 minutes of exposure to a shooting game in VR, contrasting with earlier reported impacts on decision times. Similarly, Vlahovic et al. (2021) found numerical, but not statistically significant, changes in simple and complex RT following 20 minutes of exposure to various VR games across different genres and intensities. It is possible, however, that these non-significant findings may result from the small sample sizes used in these latter studies in comparison to the previous research reported above. As well as these non-significant results, other studies suggest that VR training can be leveraged to *improve* RT. For example, training participants with Beat Saber over multiple sessions resulted in lower decision and movement RTs in amateur esports athletes (Lachowicz et al., 2025). Accordingly, the context in which RT changes are assessed is likely to be highly important in determining the exact impact of VR on these aftereffects.

Memory

Interestingly, it has been suggested that the immersive nature of VR might lead to confusion regarding memory sources, with individuals believing that they had encountered objects or scenarios in reality which they had in fact only seen within the virtual world (Hoffman et al., 2001; Rubo et al., 2021; Segovia & Bailenson, 2009). Retrieving the source of a memory is thought to depend on qualities associated with it (Johnson et al., 1993), with memories for real events being easier to retrieve and associated with more vibrant and detailed perceptual, semantic, and affective cues than memories for imagined or unreal events. In line with this idea, Hoffman et al. (2001) found that the qualities of memories differed depending on whether the participant reported the source as real or virtual, with memories for virtual objects being rated as lacking in detail compared to real objects. Moreover, false memories (i.e., reporting newly-seen items as previously-seen) tended to be labelled as virtual objects, presumably due to the lower quality of the 'memory' associated with it.

As VR technology becomes more immersive, however, it might be possible for greater confusion between memories for real and false events. Segovia and Bailenson (2009) reported that children generated false memories for events they had encountered only VR, with these false memories for virtual events associated with richer detail in line with the source memory hypothesis described above. Moreover, Rubo et al. (2021) found more memory source attribution errors between VR and real items vs items presented on a computer monitor and reality, suggesting the immersive nature of VR can generate greater source confusions. Together, this initial evidence suggests that VR has the potential to create confusion regarding the source of memories, although it should be noted that the above studies were designed to specifically investigate false memory in VR, rather than false memories arising spontaneously via general VR exposure. As such, further research is needed to establish whether false memories could be another cognitive aftereffect of VR.

Other cognitive functions

Beyond RT, other cognitive impacts have received little systematic attention, with few statistically significant findings across tasks (Mittelstaedt et al., 2019; Smith & Burd, 2019; Szpak et al., 2019; Varmaghani et al., 2022). For example, Varmaghani et al. (2022) investigated spatial working memory, spatial transformation, and sustained and divided attention following 15 minutes of exposure to a VR rollercoaster or 15 minutes of playing a board game in the control group. While control participants showed improvements in spatial reasoning and sustained attention during their post-test assessment, participants in the VR group showed no improvements, suggesting that VR impaired the consolidation of learning these tasks. Tests of divided attention and spatial working memory were unaffected by VR exposure, with both control and experimental groups showing improvements in their post-test. Conversely, Szpak et al. (2019) found no impact of VR on a rapid serial processing task, indicating no impact of VR on sustained attention in contrast to previous findings. Moreover, further studies have found little impact on VR on mental rotation and response inhibitions, although there was a non-significant numerical trend towards VR exposure resulting in worse visual search performance (Mittelstaedt et al., 2019; Smith & Burd, 2019). Overall, however, it is hard to draw firm conclusions on the broader impact of VR on cognitive aftereffects due to the disparate nature of the studies conducted in this field.

Other effects

Depersonalisation and Derealisation

Recent evidence is emerging that VR can induce sensations of depersonalisation and derealisation (DPDR): a feeling of disconnect from the self and the world. In general, DPDR is prevalent in the wider population, with estimates suggesting up to 74% of individuals will have at least transient DPDR experiences across their lifetime, while 1-2% will have symptoms severe enough to require treatment (Hunter et al., 2004). VR exposure may be a specific trigger for DPDR experiences, with a recent survey indicating that 84% of VR users experience symptoms after playing (Taveira et al., 2022). Studies of DPDR following VR exposure suggest that symptoms appear to emerge early after beginning regular VR use, but subside over subsequent exposures (Aardema et al., 2010; Barreda-Ángeles & Hartmann, 2023; Peckmann et al., 2022). Aardema et al. (2010) reported significantly higher levels of DPDR following 25 minutes of exploration in a virtual environment presented on an I-Glass HMD. Moreover, participants who had higher initial tendencies towards DPDR had subsequently higher levels of DPDR post-immersion. To explore whether DPDR was associated with VR specifically, Peckmann et al. (2022) conducted an investigation of DPDR following exposure to an open world exploration game presented on a PC screen or HTC Vive HMD. They found that participants in the VR group had significantly higher DPDR compared to the computer group, supporting the idea that immersive VR worsens DPDR symptoms. However, these symptoms did not persist beyond the immediate measure, suggesting that symptoms might not be long-lasting. It has been suggested that DPDR symptoms are linked with to the illusion of Presence – the feeling of "being there" in a virtual environment (Slater et al., 1994, 2022). In effect, the more present one feels in a virtual environment, the less present one feels on returning to 'objective' reality. In support of this, Aardema et al. (2010) found this pattern of results, with participants reporting a lower sense of presence in objective reality alongside increased depersonalisation symptoms. While this explanation seems intuitive, it is important to consider that Presence itself is a complex illusion consisting of different components, such as the Place Illusion (the feeling of being located in a virtual space) the Plausibility Illusion (the sense that the virtual environment behaves as expected), and embodiment (the feeling of owning a virtual body) (Slater et al., 2022). Accordingly, it is possible that different elements of Presence may play different roles in the development of DPDR, and specific studies are needed to disentangle this relationship.

Anecdotal aftereffects

In addition to DPDR, it is possible that other aftereffects may be experienced by VR users, but are not fully captured by the empirical research currently being conducted. A compelling review of symptoms reported by VR users on social media forums raised a range of potential aftereffects which have not yet been fully tested (Porter II & Robb, 2022). As with the above lab studies, depersonalisation and derealisation were often reported, with VR users reporting that they had a loss of the self and detachment from their body following exposure to VR, and that the world appeared more "flat" and objects did not feel "real". VR users also frequently reported having to verify the reality of objects through touch. The sense of disconnect was also reported alongside disrupted ownership of the hands and limbs, and with altered proprioception – potentially reflecting some of the sensorimotor aftereffects discussed earlier. Moreover, VR users reported altered object interactions, such as attempting to lift objects using actions associated with HMD controllers, rather than making grasping movements. In addition, they also reported altered self-motion actions, such as anticipating the use of teleport locomotion, more hesitation in anticipation of boundary/chaperone systems limiting their movements, and reluctance to physically lean on objects for support until verifying that they are solid. Visual effects included a loss of depth perception, persistence of virtual objects such as boundaries and pixels, and altered perception of text, which appears more three-dimensional than the rest of the world around the user. Importantly, these thematic findings were replicated in a sample who were given VR headsets to use 5-10 hours per week over four weeks. Curiously, VR users reported that aftereffects appeared with longer exposures, generally requiring at least 1 hour of exposure before such effects became prominent, in contrast to empirical studies reported above which find little impact of exposure time on aftereffects. This contrast with reported findings may be linked to the frequency of exposure, with aftereffects being more prominent in users who regularly play VR, versus empirical studies which generally require participants to engage in a single session of exposure. With a few weeks of regular VR use, however, VR users report that aftereffects are significantly reduced. Repeated exposure has been previously shown to reduce cybersickness (Duh et al., 2002), but its impacts on aftereffects are underexplored. Moreover, some research suggests that repeated exposure may have beneficial effects on cybersickness only when repeatedly exposed to the same game/application, and does not generalise to other virtual environments (Palmisano & Constable, 2022). Whether this is the case for aftereffects remains to be seen.

Summary

Overall, the literature together suggests evidence for VR-induced changes to sensorimotor functioning, oculomotor functions, cognition, and emotion. A list of consistently supported aftereffects is reported in Table 1. In general, all of these domains, plus the anecdotal reports by VR users, require further systematic investigation. By far the most research has been conducted on sensorimotor function, strongly suggesting changes to proprioception, hand-eye coordination, and postural instability (Biocca & Rolland, 1998; Champney et al., 2007; Cobb, 1999; Harm et al., 2008; Park & Lee, 2020; Stanney et al., 1999; Stanney & Kennedy, 1997). However, much of this research, particularly relating to proprioception and coordination, has been conducted using now-obsolete VR headsets, which use different methods of interacting with the virtual environment (e.g., use of a computer mouse or joystick, vs haptic controllers or hand tracking prevalent in modern headsets). Accordingly, while previous literature suggests robust effects of VR on sensorimotor control, this literature requires replication using modern technology to explore whether such changes remain an issue for VR use.

Investigations of changes to oculomotor functions suggest relatively consistent impacts of VR exposure on accommodation and some studies also suggest changes to vergence (Mohamed Elias et al., 2019; Szpak et al., 2019, 2020; Yoon et al., 2020, 2021), although contradictory findings have also been reported (Drouot et al., 2021; Ha et al., 2016; Turnbull & Phillips, 2017; Tychsen & Foeller, 2020). Many VR users report broader symptoms, such as blurred vision, headaches, and sore/fatigued eyes, although there seems to be little relationship with these subjective symptoms and accommodation/vergence changes (Drouot et al., 2021; Yoon et al., 2021). It is possible that there is an association between oculomotor changes and the type of virtual environment, with interactive and intense games evoking greater changes than passive and less intense games, although this relationship would benefit from further exploration.

Cognitive changes have only just started to come under investigation. However, relatively robust findings suggest increases in reaction times may be common following VR exposure (Mittelstaedt et al., 2019; Nalivaiko et al., 2015; Nesbitt et al., 2017; Szpak et al., 2019, 2020), although some contradictory findings have been noted (Szpak et al., 2022; Vlahovic et al., 2021). It has been suggested that RT increases may be associated with cybersickness, with participants who have higher levels of sickness believed to have slower RTs, although thus far the evidence for this is not strong. Broader cognitive changes, for example to sustained attention, working memory, and visual search have reached no consensus in the literature (Szpak et al., 2022; Varmaghani et al., 2022), and further research is needed.

The impact of VR on depersonalisation/derealisation symptoms also appears to be consistently supported by the literature and by anecdotal reports by VR users (Aardema et al., 2010; Barreda-Ángeles & Hartmann, 2023; Peckmann et al., 2022; Porter II & Robb, 2022; Taveira et al., 2022). However, the relationship between DPDR and length of VR exposure, persistence of symptoms, and Presence requires further research. Moreover, VR users appear to report a range of aftereffects which are not captured fully by empirical literature, such as altered object interactions, self-motion perception, and visual disturbance beyond oculomotor function (Porter II & Robb, 2022). Thus, it would be beneficial to target specific aftereffects on the basis of the experiences of real VR users to guide future research.

Table 1.
Summary of Key VR aftereffects

Domain	Aftereffect	Magnitude and duration	Citations	Additional information
Sensorimotor	Proprioceptive disruption and coordination errors	Small (<10cm) pointing errors, up to 6 hours post-exposure	Biocca & Rolland, 1998; Champney et al., 2007; Harm et al., 2008; Stanney et al., 1999; Stanney & Kennedy, 1997	Most studies use obsolete VR headsets - this area requires further exploration using modern VR HMDs. Few studies investigate timecourse, focusing on immediate effects
Sensorimotor	Postural instability	Increases in sway velocity, variable duration with some studies reporting recovery within 10 minutes and others reporting persistent sway for >1h post-exposure	Champney et al., 2007; Cobb, 1999; Horlings et al., 2009; Park & Lee, 2020	Generally accepted that VR induces postural instability, possibly linked to visuo-vestibular conflicts. Many studies focus on postural instability and its relationship to cybersickness, but further studies on persistence of effects and relationship to VR environment characteristics are necessary
Oculomotor	Near point accommodation/vergence changes	Increases in near point accommodation distances, with some limited evidence for changes to vergence too. Recovery potentially rapid, within 1h of VR exposure	Mohamed Elias et al., 2019; Szpak et al., 2019, 2020; Yoon et al., 2020, 2021	Potential association with the intensity and interaction style of the virtual environment, with interactive games and intense experiences possibly associated with greater oculomotor symptoms. Conflicting findings, with some studies reporting little impact on accommodation/vergence, despite other symptoms (blurred vision, sore eyes etc.) being prevalent
Vestibular	Vestibular reflex changes	Vestibulo-ocular reflex gains decreased and vestibular-evoked myogenic potential asymmetry	Di Girolamo & Pic, 2001;	Further investigation is needed, given that the studies used older VR headsets, specific visual stimuli, and did not

		increased following VR exposure. Studies only investigated changes immediately post-VR	Gallagher et al., 2019, 2020	investigate persistence of vestibular changes post-VR
Cognitive	Reaction Time	Increases in reaction time, with potential rapid recovery (within 1h)	Mittelstaedt et al., 2019; Nalivaiko et al., 2015; Nesbitt et al., 2017; Szpak et al., 2019, 2020	Some conflicting findings from studies with smaller sample sizes. VR has also been used to train reaction times in athletes, suggesting not all applications result in slower RTs
Cognitive	Memory	Potential for VR to induce false memories, with confusion regarding the source of memories	Hoffman et al., 2001; Rubo et al., 2021; Segovia & Bailenson, 2009	Studies have not been designed to investigate false memory as an aftereffect of VR, but rather to investigate false memory in general
Other	Depersonalisation/Derealisation	Prevalent DPDR symptoms across a large number of VR users. Cross-sectional studies suggest recovery immediately after exposure, but other studies suggest that symptom duration may be associated with frequency of VR use. Specifically, it seems likely that DPDR symptoms are worse when beginning regular VR use, but decrease after subsequent exposures.	Aardema et al., 2010; Barreda-Ángeles & Hartmann, 2023; Peckmann et al., 2022; Taveira et al., 2022	Suggested that DPDR is associated with Presence - feeling more Present in the virtual world creates a sensation of lower Presence in the real world. Further studies are needed to disentangle this relationship

Mechanism

The precise mechanism driving aftereffects is not understood, although several aspects are likely to have significant influences on their development. Firstly, during VR exposure, the brain is faced with alterations in expected sensory information. For example, consider riding a rollercoaster in the real world: vision, proprioception, and the vestibular system all signal that you are moving in a certain direction with a certain acceleration. In a VR rollercoaster, however, vestibular and proprioceptive information do not match the visual information regarding your movements through the world: vision signals that you are accelerating, while the other sensory systems signal that you are stationary. Accordingly, the brain must re-weight incoming sensory information to minimise prediction error and generate coherent percepts regarding self-motion. It is well-established that such sensory conflicts are associated with the development of cybersickness (Gallagher & Ferrè, 2018; Khalid et al., 2011; J. Kim et al., 2021; Rebenitsch & Owen, 2016). However, their relationship to aftereffects is not yet fully known. It is possible that the re-weighting of sensory cues could impact aftereffects directly. For example, a down-weighting of vestibular signals seems a plausible explanation for altered vestibular reflexes and perception following VR exposure (Di Girolamo & Pic, 2001; Gallagher et al., 2019, 2020). Given the vestibular system's extensive influence on behaviour, perception, and cognition (Angelaki & Cullen, 2008; Besnard et al., 2016; Ferrè & Haggard, 2020), disrupted vestibular processing could thus plausibly play a role in disrupted postural stability, increased DPDR, and altered spatial perception following VR exposure. Re-weighting of visual signals has also been shown to result from VR exposure (Chung & Barnett-Cowan, 2023), which might suggest that re-weighting of specific modalities could impact different aftereffects. As well as downweighting, it has been suggested that processing a sensory conflict itself requires the allocation of cognitive resources, which could drive cognitive aftereffects of VR exposure (Nalivaiko et al., 2015; Szpak et al., 2019). It is important that future research evaluates this possibility directly, potentially through altering the magnitude of conflict and measuring weights allocated to different sensory systems following VR exposure.

Secondly, it has been argued that cybersickness and presence may play a role in the development of aftereffects, such that the greater the level of cybersickness, the worse the VR aftereffects. Correlations between cybersickness severity and specific aftereffects such as reaction time slowing and oculomotor disturbance have previously been reported, supporting the idea of a link between the two (Nesbitt et al., 2017; Szpak et al., 2019; Yoon et al., 2021). However, other studies have found little relationship between cybersickness and aftereffects, and many further studies often do not directly test for associations between aftereffects and symptoms of cybersickness (Mittelstaedt et al., 2019; Szpak et al., 2022; Varmaghani et al., 2022). Moreover, correlations in themselves do not rule out a common cause of both cybersickness and aftereffects, without a direct relationship between the two. In addition to cybersickness, Presence may also be closely associated with aftereffects, being the prevailing explanation for DPDR as discussed previously (Aardema et al., 2010; Barreda-Ángeles & Hartmann, 2023; Peckmann et al., 2022). Interestingly, an inverse relationship has been reported between presence and cybersickness (Weech et al., 2019), and accordingly it may be interesting to consider each of these factors and their relationship to aftereffects more broadly.

Finally, technological aspects such as display lags, field of view restrictions, and method of interaction also require the brain and sensory systems to adapt to the altered VR environment, potentially resulting in aftereffects. Physical factors, such as the weight of a head-mounted display, may also play a role in the development of aftereffects through inducing fatigue and placing increased physical demand on the user (Irminanda & Xiong, 2025; Kazemi & Lee, 2023). Moreover, navigation through and interaction with virtual worlds may require the use of hand controllers and altered locomotion techniques such as teleportation. These altered mechanisms may require a certain amount of adaptation, facilitating action in the virtual world, but resulting in aftereffects when returning to the real world (Porter II & Robb, 2022). Finally, differences in game or application type, such as intensity and locus of control, may also place different demands on the VR user. Such differences are known to impact cybersickness intensity (Mayor et al., 2021; Stanney & Hash, 1998), but further work is needed to understand their role on aftereffects. Many of the previously reviewed studies use diverse HMD types, with differences in their refresh rates, field of view, controller type, and application, making the exact contribution of each of these factors difficult to ascertain.

These mechanisms have not been directly empirically tested in relation to VR aftereffects, and it is likely that all contribute and overlap to some degree. In addition, whether some aftereffect domains may be more impacted by one or another of these mechanisms is yet to be explored. Interestingly, the domains of aftereffect reported in the literature appear to mirror other situations in which sensory conflicts are present – specifically in the case of microgravity. Exposure to microgravity also disrupts the relationship between vestibular and other sensory modalities (Clarke & Schönfeld, 2015; Edgerton, 2001; Holly & Harmon, 2012), mirroring the sensory conflicts which may be present in many VR applications. In particular, exposure to microgravity results in changes across sensorimotor, oculomotor, cognitive and emotional domains

(Arshad & Ferré, 2023). It has been suggested that two potential neurocognitive accounts can explain these microgravity effects (Arshad & Ferré, 2023). Firstly, an independent model in which each domain is independently modulated by microgravity. Secondly, a cascade model, in which cognitive and emotional domains are driven by alterations in sensorimotor functioning. Given the clear similarities in sensory disruption across VR and microgravity, it remains to be seen whether either of these models is also applicable to VR aftereffects. Future research should therefore investigate whether each of the domains reported above is independently impacted by VR, or whether a similar cascade model driven by sensorimotor alterations could account for these effects.

Suggestions for future research

At present, relatively little attention has been given to VR aftereffects in comparison to cybersickness, and in general the existing research is not systematic, with considerable variation in the type of VR HMDs, controller types, exposure times, applications, experimental designs, and sample sizes. Moreover, many studies use pre/post designs, which cannot fully rule out the role of fatigue or other non-specific factors that may drive aftereffects, and do not assess for how long aftereffects persist. Given the varied interests within this field, there is unlikely to be a "one size fits all" design encompassing all possible research questions. However, researchers should take care to ensure that they adequately report their materials and measures, consider adequate sample sizes to account for small effects, and, wherever possible, consider the use of non-VR control groups which complete comparable tasks to the VR exposure in order to control for non-specific effects. Moreover, future studies should more closely investigate factors such as exposure time, application type, levels of cybersickness, and interaction methods to further clarify their role in the development of aftereffects.

In addition, much research across the aftereffects literature is lab-based, and may not necessarily reflect the day-to-day experiences of VR users. For example, while lab experiments might expose VR users to a brief exposure of a single game for a fixed duration, actual VR users may instead have longer sessions over repeated periods, playing a variety of games and other applications. Such factors may account for the disparity in lab effects versus effects reported by VR users (Porter II & Robb, 2022). While several studies report little impact of exposure time on aftereffects (Risi & Palmisano, 2019), they still may not reflect the levels of exposure of regular VR users. Accordingly, designs which use longer and/or more frequent exposures to VR reflecting typical VR use would be helpful to build evidence towards the role of these factors in the development of aftereffects. One example from Steinicke and Bruder (2014) immersed a single participant in VR for 24 hours, with only short breaks every 2 hours, to investigate the development of cybersickness and presence over time. Notably, however, they did not further explore these measures following termination of the experiment, missing the post-VR period and preventing analysis of aftereffects resulting from this long-duration exposure. In addition, researchers might also consider comparing regular VR users versus novice VR users to explore the process of adaptation to VR across time.

Finally, much of the evidence presented in the present review has focused on aftereffects of VR exposure. Recently, however, Augmented Reality (AR), which blends elements of the real world with virtual objects, is becoming more prevalent, but has received little attention scientifically in comparison to fully immersive VR. There is growing evidence that AR can also induce cybersickness (Drouot et al., 2021; Duan et al., 2024; Hughes et al., 2020; Kaufeld et al., 2022), but its impact on aftereffects is less researched. As previously discussed, Biocca and Rolland (1998) found changes in hand-eye coordination after using video passthrough, suggesting AR has the potential to induce aftereffects similar to VR. Similarly, Bailenson et al. (2024) conducted a study in which authors wore passthrough headsets and self-reported alterations in distance perception, body perception, and sickness during several hours of immersion. However, it is not clear whether or how long these effects persisted following headset removal. Moreover, similar findings were reported in an autoethnographic study, in which the author reported disrupted sensory information when walking while wearing a video passthrough HMD, a feeling of 'losing' the ground and relying on visual feedback when moving (Sun & Schöning, 2025). In contrast, Santoso and Bailenson (2024) found no aftereffects of exposure to an AR body transfer task, suggesting limited impacts of AR.

Recent technological advancements have also given rise to different forms of augmented reality. Video passthrough devices resemble 'standard' VR HMDs, with cameras used to project images to the HMD screens. However, other passthrough devices, commonly referred to as Smart Glasses, have transparent lenses onto which virtual objects are projected. Accordingly, it is possible that these two types of AR device might have different impacts on the AR user. For example, video passthrough devices may be subject to similar technological impacts as fully immersive VR, with lags, low resolution, and refresh rates contributing to cybersickness (Allison & Palmisano, In Press) and aftereffects through sensory conflict or other mechanisms. In contrast, transparent lenses might reduce these impacts, allowing participants to interact with the real world without technological interference, potentially reducing cybersickness and aftereffects. Research using a Microsoft HoloLens device, which used transparent lenses to project virtual objects onto a view of the real world, reported low cybersickness symptoms across multiple applications (Vovk et al., 2018). However, severe cybersickness symptoms were reported when projecting dynamic stimuli onto the real world using the same device (Kaufeld et al., 2022), suggesting the content of the AR application might play more of a role than the device per se. Neither study investigated aftereffects. Moreover, both types of AR device could evoke cybersickness and/or aftereffects through poor blending of real and virtual worlds, for example via issues such as conflicts in real-world lighting and lighting of virtual objects (photometric mismatch), challenges of virtual object occlusion, reduced image quality and field of view displacement, although there is limited evidence at present regarding the contribution of such issues to cybersickness and aftereffects. Given the rapid uptake of AR-enabled devices, significant work is needed to bridge the gap in our understanding of the impacts of AR on aftereffects.

Implications for VR Users and Designers

While much more research is necessary into the scope of VR aftereffects, several considerations are apparent for VR users. Given the scope of aftereffects reported in the literature, activities such as driving and operating heavy machinery immediately following VR exposure could potentially pose safety risks, particularly given potential changes to reaction time, vision, and hand-eye coordination discussed in this review. Thus, VR users must consider broader impacts on their perception and cognition before engaging in such activities shortly after VR exposure. Pertinently, many VR manufacturers propose safety guidelines such as including frequent breaks, avoiding prolonged exposure, and provide ‘comfort ratings’ for VR applications (HTC Corporation, n.d.; META, n.d.), which potentially mitigate against both cybersickness and long-lasting aftereffects. However, individual differences make specific recommendations and guidelines harder to establish, while comfort ratings are typically associated with immediate impacts of cybersickness rather than the potential for later aftereffects. Given our lack of understanding of the duration and development of many aftereffects, further investigation as to their time-course would be prudent to make specific recommendations to VR users.

Much of the present research has focused on VR gaming in the development of aftereffects, but less is known regarding other uses such as workplace/industrial applications or virtual desktops (Berg & Vance, 2017; Choi et al., 2015). Given the general lack of motion and reduced intensity of these scenarios, it is possible that VR aftereffects are less prevalent in such cases vs VR gaming, given the potential lower levels of immersion and sensory conflict. When considering VR training applications, there is a clear benefit for VR training in particular industries, especially when real-world exposure to such training cases could be dangerous or unfeasible (Alaker et al., 2016; Y. Kim et al., 2017; McIntosh, 2022). Moreover, training applications in sport shows improvements to functions such as reaction time and coordination, suggesting benefits, rather than drawbacks, of VR exposure (Lachowicz et al., 2025). However, consideration of unintended aftereffects remains important, for example when training fine motor skills such as in surgical training, given the potential for disrupted sensorimotor functioning post-exposure (Harm et al., 2008; Stanney et al., 1999). As such, applications of VR to industry would benefit from monitoring relevant aftereffects post-exposure.

Finally, there is a burgeoning interest in using VR in clinical settings for diagnosis and rehabilitation. For example, VR applications can be useful in improving cognitive outcomes in patients with schizophrenia (Gillouin et al., 2024), upper limb function after stroke (Laver et al., 2025), and in improving phobias through VR exposure therapy (Freitas et al., 2021). While many studies consider the impact of cybersickness on these populations when discussing VR safety and tolerability (e.g., Moon et al., 2025; Specht et al., 2021), it would seem prudent to also consider monitoring patients in the short-term following VR exposure to screen for unintended aftereffects. In addition it is also important to consider whether use of VR is appropriate in many clinical populations, given the potential to induce aftereffects such as postural instability or depersonalisation/derealisation, which have the potential to worsen the condition presented by patients prior to exposure.

Conclusion

Overall, the present field shows that it is possible for VR to induce a range of aftereffects, but the full extent of these effects is unknown. Research has generally focused on aftereffects in sensorimotor, oculomotor, and cognitive domains, while emerging studies suggest effects on the sense of self and body perception may be common in the real world. The field in general uses disparate VR hardware, applications, exposure times, sample sizes, and aftereffect measures, making it difficult to underpin exact mechanisms driving each of these effects. It is possible that sensory conflict, cybersickness, presence, and technological features play a role across one or all of these aftereffect domains. Finally, while the aftereffects of VR have been reviewed here, augmented reality (via video passthrough or see-through displays) also has the potential to induce similar effects. With the growing popularity of extended reality, it is imperative that research continues to study the lingering impacts of this technology on perception and cognition. Future studies using standardised techniques will help to uncover the domains and mechanisms of aftereffects, and pave the way to improving VR's effect on the brain.

Declarations

Competing Interests

The author confirms no financial or non-financial interests directly or indirectly relating to this work.

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Compliance with Ethical Standards

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