Enduring Immersion: Persuasiveness of Multidimensional Immersive Experience

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Abstract: Immersive experience can be understood as the perception of being enveloped in a virtual environment. Common approaches include using virtual-reality (VR) headsets, 360-degree projections, or huge LED screens to create an illusion of being surrounded by another reality. Fully immersive experiences have proved effective in influencing attitudes and even behaviors. Meanwhile, partly immersive experiences via displays blended in physical settings can be persuasive too. This theoretical paper first reviews the notion of immersion in relation to a few nuanced concepts, followed by analyses of an array of innovative artifacts from the panorama, diorama, handscroll, web or device interfaces, to video games, arguing that immersive experience, as a long-lasting human creative pursuit, is multidimensional. It includes two characteristics, namely perceptual distance to a space and emotional involvement in a scene. While some artifacts are prominent only in one dimension, others span multiple dimensions, featuring "enduring immersion." Enduring immersion allow people to vary their distances to a virtual space and involvements in a virtual scene at different times, hence enabling integration of computer simulation into daily context, prompting mental simulation in people, and influencing their intentions and behaviors, forming the "post-reality feedback loop." In view of this persuasive socio-technological phenomenon, ethical considerations of designing and developing related immersive experiences are discussed.

Keywords: Immersive experience, Interactive media, Cultural artifacts, Video games, Post-reality feedback loop.

1. INTRODUCTION

Immersive experience, enabled by computing and related technologies, can be understood as the perception of being enveloped in a virtual environment toward a feeling of isolation from the real world (Cummings & Bailenson, 2016; Lombard & Ditton, 1997; Patrick *et al*., 2000; Witmer & Singer, 1998). Common approaches to immersive experiences of today include using virtual-reality (VR) or mixed-reality (MR) headsets with built-in head-tracking sensors and head-mounted displays (HMDs) that show a corresponding view in accordance with the detected head movement, or using multiple image projectors or cylindrical LED walls to present 360-degree borderless images surrounding the viewers. Some researchers call virtual environments that are presented on borderless room-based projections or HMDs as "high-immersive" (Checa & Bustillo, 2020) or "fully immersive" VR (Alnagrat *et al*., 2022; Speicher *et al*., 2019), those on large screens or projections blended in physical environments as "partly" or "semi-immersive" (Alnagrat *et al*., 2022; Speicher *et al*., 2019), and those on hand-held or desktop displays (e.g., in mobile or computer games) as only "low-immersive" (Alnagrat *et al*., 2022; Checa & Bustillo, 2020).

Immersive experience can be persuasive. Using HMDs to fully immerse people in simulated, hypothetical scenarios, even though for a brief period of time, has proved effective in influencing attitudes and intentions (Ahn *et al*., 2016; Hershfield *et al*., 2011; Oh *et al*., 2016; Yee & Bailenson, 2006, 2007). Meanwhile, the so-called "partly or semi-immersive" experiences can have psychological effects too. Norouzi and colleagues (2019; 2022) show that a virtual dog, which is perceivable in a physical setting via an optical see-through headset with micro-projections (Microsoft Hololens), can mitigate anxiety in stressful situations and bring about positive emotions in participants. Chow (2021) reports that a digital picture frame, which simulates and displays virtual dust on a picture next to a burning cigarette on an ashtray, incrementally influences participants' intention and determination to reduce smoking on a daily basis. These studies suggest that even partly immersive experiences can be persuasive.

Instead of categorizing immersive experiences into different levels (Brown & Cairns, 2004; Speicher *et al*., 2019), this article considers immersion as a non-linear, continuing process of "stepping into another world" and suggests a new analytical framework. As Grau (2003) puts it, immersion is characterized by "diminishing critical distance to what is shown" and "increasing emotional involvement in what is happening" (p. 13). This article examines these two characteristics of

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immersion through analyses of an array of innovative artifacts across different historical periods and cultures. It first differentiates immersion from related concepts. It then argues that immersive experience, as a long-lasting creative human pursuit, spans two paradigms, namely immediate and enduring immersion. Immediate immersion refers to the kind of fully immersive experience that emphasizes "being present in" a virtual space of another world, which implies a total separation from physical reality for a period of time. Enduring immersion refers to the kind of partly immersive experience that allows varying distances to another world and involvements in the happenings there, which does not necessarily shut out physical reality. Instead, enduring immersion enables one to stay close to a virtual setting in another world, intermittently step into it, notice changes, and track happenings in that world at any time. From pre-digital attempts to contemporary digital approaches to immersive experience, computer simulation replaces pictorial representation as the means to the illusion of another reality. Enduring immersion integrates computer simulations in daily settings, prompts users' imagination, and influences their intention and even behavior, forming what is called the "post-reality feedback loop." In view of this persuasive socio-technological phenomenon, ethical considerations of designing and developing related experiences are discussed.

2. RELATED CONCEPTS

The term "immersion" literally means "submerging in a liquid." In the context of contemporary media, it is metaphorical. Murray (1997) provides one of the earliest interpretations: "the sensation of being surrounded by a completely other reality" (p. 98). She also takes user participation into account, envisioning that "immersion implies learning to swim, to do the things that the new environment makes possible" (ibid., p. 99). The swimming analogy suggests that users are not only passively "being surrounded" but also able to navigate and explore in the virtual space. Ryan (2015), taking a literary perspective, expands the notion of immersion from exploration in space or place (i.e., spatial immersion), to involvement in the "process of disclosure" in narrative (what she calls "temporal immersion") and feeling curious, to emotional attachment to (e.g., like or dislike) and even empathizing with (e.g., feeling happy or sad) a fictional character (what she calls "emotional immersion"). The expanded notion of immersion from space, to narrative, to characters, resonates with views in game studies. Brown and Cairns (2004) suggest that immersion is a graded experience, from investment of time, effort, and attention in a game, to being emotionally affected by it, to empathizing with a game character. These interpretations put immersion in relation to a few nuanced concepts.

2.1. Narrative Transportation

Belisle summarizes immersion as "a state of engagement in which viewers or users feel transported into and absorbed by the world of a representation" (Belisle, 2016, p. 247). Being "transported" or "absorbed" here is also metaphorical, related to "suspension of disbelief" in literary theory and "narrative transportation" in psychology, a mental process of being absorbed into a story via mental imagery, affect, and focused attention, which makes some aspects of the real world inaccessible in favor of accepting that narrative world, like reading a novel or watching a movie (Gerrig, 1993; Green & Brock, 2000; Oatley, 1999). A person needs to suspend reality-testing in order to make sense of a fictional narrative (Holland, 2008). The inaccessibility to some real-world aspects in transportation starts to provide necessary conditions for the illusion of presence (Witmer & Singer, 1998).

2.2. Presence

"Presence" means a sense of being there and can be defined as an "illusion that a mediated experience is not mediated" (Lombard & Ditton, 1997), resulting in a "subjective experience of being in one place or environment, even when one is physically situated in another" (Witmer & Singer, 1998). By definitions, immersion, as the perception of being enveloped in a virtual environment (Patrick *et al*., 2000), can facilitate presence, as the illusion of being in it (Cummings & Bailenson, 2016). While some literature subsumes immersion in presence (Lombard & Ditton, 1997; Witmer & Singer, 1998), Slater and Wilbur (1997) differentiate immersion as an objective measure of sensory fidelity (e.g., images) of a virtual environment and presence as a subjective experience (e.g., mental imagery) of the user resulting from being in it. Anyhow, presence depends on a pre-assumption of immersion that is the feeling of isolation from physical reality (Cummings & Bailenson, 2016). From transportation to presence, the access to real-world aspects is diminishing.

2.3. Involvement

Witmer and Singer (1998) state that, besides immersion, involvement is another necessary condition for presence. Involvement is “a psychological state experienced as a consequence of focusing one’s energy and attention on a coherent set of stimuli or meaningfully related activities and events” (Witmer & Singer, 1998). Here, a person pays not only attention but also effort (mental or physical), such as a reader of a novel bringing the paperback version while commuting, or someone watching a television show on a video streaming platform cannot help pressing the “skip intro” button to continue with the next episode. When a person attends to and interacts with some responsive items in a virtual environment, they feel involved in that world.

2.4. Flow

When a person is transported into another world, pay much attention and energy to it, they feel not just isolated from reality but actually forget it, reaching a state of flow, which is “the state in which individuals are so involved in an activity that nothing else seems to matter” (Csikszentmihalyi, 2008). In playing an exciting game, for instance, the real world can be “cut off” from the players (Csikszentmihalyi, 1975). As Jennett and colleagues (2008) put it, flow is the extreme end of immersion.

All in all, narrative transportation engages one’s mental imagery, affect, and focused attention in another world and disengages one from some real-world aspects. When sensory representations of that world become vivid, dynamic, and responsive, one feels being involved, present in it, and even cutoff from the real world. If they invest much attention and energy, becoming so involved, they may sense flow. Among these processes, immersion plays a definite role, via sensory representations that invite one to approach, notice, and track happenings in that world. Immersion is not just about different degrees of sensory fidelity of a virtual environment, or different levels of mental involvement in another world, but a non-linear, continuing process of stepping into another world, allowing one to travel back and forth among transportation, involvement, presence, and flow (see Figure **1**).

3. TWO CHARACTERISTICS OF IMMERSION

Immersion is a non-linear, continuing process of stepping into another world. Grau (2003) characterizes the process of immersion in two aspects, namely “diminishing critical distance to what is shown” and “increasing emotional involvement in what is happening” (p. 13). The first characteristic implies a range of illusions, varying from “being adjacent to an extended space” to “being present in a separate space”. The second characteristic describes the amount of energy that one exercises in another world, from “paying attention to changes” to “paying effort to track events.”

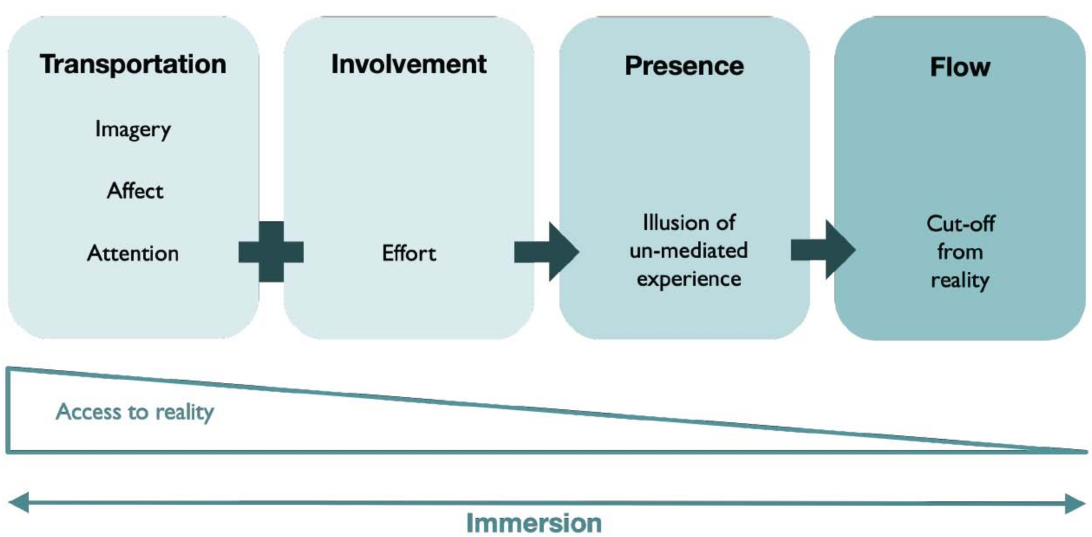

Figure 1: A relationship diagram connecting transportation and involvement to presence and finally flow, with diminishing accessibility to the real world, meanwhile immersion as a process that allows traversing among different states.

3.1. Distance to A Space: "Adjacent to an Extended Space"

The first characteristic relates spectators to a virtual space projected by a medium in terms of how close they are. As an art and media historian, Grau starts with case studies on frescoes from ancient to medieval European architecture, which are intended to be "views into other spaces," in other words, a form of "extended space and reality" (p. 72). Grau then discusses the Robert Parker's Panorama Rotunda in the 18th century of Europe, which depicts a 360-degree view in correct perspective on a completely circular canvas on the inner wall of the rotunda (p. 56). From frescoes to panoramas in round buildings, the first characteristic of immersion, about a spectator's perceptual distance to a virtual space, can be described in two states, namely feeling "adjacent to an extended space" or feeling "present in a separate space." This section and the next discuss innovative artifacts corresponding to the two states.

Frescoes

Many frescoes in historical buildings that survive today are tangible evidence of the long-lasting human endeavor to create the illusion of space. These frescoes are borderless, depicting life-sized content in correct perspective for the assumed spectator. Similar to trompe-l'œil blended in physical context, they create views into spaces extended from the real space of the spectator. Prominent examples include Andrea Pozzo's painting across the curved ceiling of the nave of Sant'Ignazio in Rome (1688–1694). The fresco creates an illusion of a roofless cathedral that opens a celestial view into the sky. As Grau (2003) describes, "Pozzo employed the techniques of illusion in order to merge the real with the painted architecture and extend it upward into heaven, as if heaven and the church space of the devout were one and the same place" (p. 46). Drawing on German literature, Grau notes that such a wall or a ceiling is no longer a tangible boundary of space, but fusing the imaginary space with the real one, and the pictorial representation extends space and reality (p. 72).

3D Anamorphic Billboards

Contemporary examples of "feeling adjacent to an extended space" include the large outdoor LED screens on building façades that show intriguing anamorphic content to public in urban districts. These screens, so-called "3D anamorphic billboards," typically display three-dimensional computer-generated images (CGIs) that simulate the perspective of viewing from the street to the façade, looking like an unusual space extended into the building, for example, a giant cat crawling in some empty floors like what a typical cat does on a bookshelf.[1] Unlike traditional trompe-l'œils, which are painted in smaller size and so can be easily seen distorted when a viewer slightly moves and changes the viewing position, 3D anamorphic billboards are so large that the illusion is mostly effective across different viewpoints on the street. Although such a billboard is literally distanced from a viewer on the street, it blends with the real building and the street to form a hybrid environment (e.g., a giant cat occupying some floors of the building) that surrounds the viewer. It is comparable to the case of Pozzo's painted ceiling with the real interior of Sant'Ignazio as a stage set that surrounds the visitor (Grau, 2003, p. 46).

3D Anamorphic Touchscreens with Eye-Tracking

To reduce the literal distance of an anamorphic display to a viewer, even to an extent that it becomes touchable, meanwhile maintaining a correct perspective for the moving viewer, innovative application of technology is required. With recent advances in technologies including computer vision, face recognition, and computer graphics, using a camera to track a user's gaze, devising their physical point of view, computing the corresponding perspective, and rendering the anamorphic image, all in real time, have become feasible in principle. A recent crowd-funded project promises to deliver a hand-held table-top pod, Dipal D1, in 2025.[2] The pod features an 8-inch curved touch-enabled screen and cameras, supposed to track the user's eye position in real time and dynamically render the 3D CGIs based on the user's viewpoint. As shown in the demo videos, the content can be a 3D animated character standing in a cylindrical compartment or on an open platform, for instance. When the user looks at the display from different angles, they can see different aspects of the character, looking like a holographic effect. The display thus opens a window into the cylindrical compartment of the pod, in which the animated character stands, or a portal into

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[1] See https://www.tokyoweekender.com/entertainment/tech-trends/3d-billboards-tokyo/
[2] See https://www.dipal.net/

another space, in which the character even walks around. Together with other features like responding to the user's gaze, voice, and gestures, the product is claimed to deliver an immersive 3D experience.

3.2. Distance to a Space: "Present in a Separate Space"

Panoramas

Frescoes in some historical sites show an illusion of a continuous space across multiple walls to address the observer from all sides, as seen in the examples discussed in Grau (Grau, 2003, pp. 25-34). These frescoes might have inspired Robert Parker, who patented the well-known Panorama Rotunda in 1787, which depicts a panoramic (a term used after this invention) view in correct perspective (based on an apparatus he invented) on a completely circular canvas on the inner wall of a rotunda (ibid., p. 56). The world's first purpose-built rotunda opened in 1793, with two stories, each had a viewing platform at the center of the building. It was dark inside the building, except overhead light cast on the painting to simulate the light source as seen in it. Visitors standing on a platform might slowly walk around to scan across the panorama that surrounds them. The painting typically showed a landscape of some remote place for the eyes of the city dwellers, for example, a panoramic view of Edinburgh was shown in London (ibid., p. 58). As Belisle (2016) puts it, "early panoramas depicted primarily scenes of cultural and historical significance, such as 'foreign' landscapes and colonial battles," which "structured colonialism, tourism, and capitalism in the early nineteenth century" (p. 252-4). They are pre-digital inventions that make people feel like being not just close to but actually stepping into another space.

CAVE, Immersive Projections, and 360-Degree Screens

The earliest digital counterpart of the medieval frescoes and the nineteenth-century panoramas is probably the CAVE, a recursive acronym of cave automatic virtual environment, invented in 1992, using multiple projectors to cast seamlessly connected images onto all the walls, and even the ceiling and floor, of a room-sized cube (Cruz-Neira *et al*., 1992). The digital images not only enable interactive dynamic content to be shown but also allow a participant wearing a stereoscope to see 3D virtual items just in front of them. The room setting has latter transformed into varied settings in different forms of wide screens, walls, domes, facades, or even physical objects, today commonly called "immersive projections" or "projection mapping." As LEDs have become increasingly affordable and accessible, large panoramic or 360-degree LED cinematic screens can be built in place of using projection.[3] These immersive systems can put an observer in a purely imaginary computer-generated virtual environment, or in a recorded real scene through a 360-degree video, such as a natural wonder[4] or a detention camp.[5]

HMDs and Immersive VR

A 3D computer-generated virtual environment or a 360-degree video scene can also be viewed on a HMD, together with sensors that track the head movement and microprocessors that render the corresponding first-person perspective in real time, constituting a VR/MR headset. Using headsets is much less costly and more flexible in use than setting up large projections or LED screens. This enables more scientific studies that put participants in immersive virtual or hybrid environments and investigate the psychological effects. For example, using VR headsets to put participants in simulated scenarios provides effective exposure therapy for phobias (Baus & Bouchard, 2014; Botella *et al*., 2017), and psycholgoical interventions for varied disorders (Rizzo & Bouchard, 2019). As a HMD offers each individual with a first-person perspective, a virtual mirror (one in the virtual environment) is commonly used to let an individual see their avatar's appearance, which a large projection or display cannot match. Studies show that a taller avatar enhances self-confidence (Yee & Bailenson, 2007), an avatar of the skin color or age different than the real person reduces negative stereotyping (Oh *et al*., 2016; Peck *et al*., 2013), transformation into non-human animals changes one's attitude toward nature (Ahn *et al*., 2016), and becoming an older self motivates one's preparation for future (Hershfield *et al*., 2011).

3.3. Involvement in a Scene: "Paying Attention to Changes"

The second characteristic of immersion is about a spectator's emotional involvement in the happenings

[3]See https://vrc.hkbu.edu.hk/en/vs/nvis.html
[4]See https://www.youtube.com/watch?v=WsMjBMxpUTc
[5]See https://www.youtube.com/watch?v=mUosdCQsMkM

presented by a medium in the form of a scene, that is, their attention and energy invested in it. Happenings transcend spaces into scenes, implying changes or a sequence of events. Traditional visual art forms such as painting seem to be intrinsically limited in showing changes. Exceptions include the diorama in the 19th century of Europe and the handscroll that emerged in East Asia as early as in the 10th century. Grau (2003) thinks that the diorama to a certain extent keeps a distance from the viewer (p. 14) and excludes it in his thesis. To people in the early 19th century, however, the diorama seems to be even more exciting and realistic than panoramas, because the diorama is able to show subtle, constant changes in a scene by combining transparent paintings and lighting effects (Gernsheim & Gernsheim, 1956, pp. 16-17). The handscroll in East Asia, on the other hand, is a distinctive format of painting on an exceedingly long horizontal scroll. The long format enables presentation of a sequence of events distributed over a wide scene (Chow, 2013, p. 19). To know what would happen next in the scene, a spectator takes action to unroll part of the scroll and let the scene unfold. Emotional involvement is embodied in action. Based on the diorama and the handscroll, the second characteristic of immersion, about one's emotional involvement in the happenings of a scene, can be described in two states, namely "paying attention to changes" and "paying effort to track events." This section and the next discuss innovative artifacts corresponding to the two states.

The Diorama

Prior to the well-known invention of the daguerreotype, Louis Daguerre also co-invented with architectural painter Charles Marie Bouton the Diorama, "an exhibition of enormous transparent paintings under changing lighting effects" (Gernsheim & Gernsheim, 1956, p. 13). In 1822, about three decades later than the Panorama Rotunda, they debuted the Diorama at a mansion in Paris, featuring their paintings. Visitors were guided to a dark chamber and seated on benches opposite an open space, resembling a large window. Through the window was seen the interior of Canterbury Cathedral, with the light and shadows changing slowly, which was then dissolved into a view of the Valley of Sarnen in Switzerland. It was noted that visitors believed what they saw was real (ibid., p. 14-15), and as a test they sometimes threw little balls of paper or coins at the picture (ibid., p. 17). Parisians found the Diorama more exciting than panoramas. While panoramas were limited to one aspect of time, the Diorama showed "many momentary changes of mood" with the "constantly changing light effects" and "illusion of depth" (ibid., p. 16-17). As the exhibition of each picture typically lasted ten to fifteen minutes (ibid., p. 17), the Diorama was an early entertainment that captured audience's attention through slowly, enduringly changing scenes.

Dynamic Wallpapers

The evolution of media technology after the daguerreotype, from photographic film and projection, magnetic videotape and cathode-ray tube (CRT) television, to computer-generated imagery (CGI) and varied digital displays, has enabled constant new updates on the kind of immersive experience like the Diorama that shows enduringly changing scenes, such as a theater ride in an amusement park featuring a forest walkthrough, an interactive projection in a museum showing responsive jellyfish, or a computer monitor screensaver displaying an animated aquarium. With advances in information technology and computer graphics, a computer operating system (e.g., MacOS) may provide a dynamic wallpaper that features a scenic view with subtly changing light and atmosphere that synchronize with the time of day at the computer user's geographical location. Such a dynamic wallpaper is a digital counterpart of Daguerre's Diorama.

3.4. Involvement in a Scene: "Paying Effort to Track Events"

The Handscroll

The long horizontal format of the handscroll not only enables the presentation of multiple points of interest distributed over the continuous canvas space, but also structures a particular order of reception along the horizontal composition. Classical examples include Gu Hongzhong's *The Night Entertainment of Han Xizai*, believed to be created in tenth-century China (Wu, 1996, p. 29), and *Chojujinbutsugiga* (Animals at Play) created around the twelfth century in Japan (Hu, 2010, pp. 26-27). This kind of work shows a long landscape of outdoor or indoor space in which same characters are recurrently involved in a sequence of events distributed across the space. For example, in *The Night Entertainment of Han Xizai*, the main character

Han recurrently appears in different parts of the painting. The first part sees him sitting on a couch and listening to a pipa with his guests and servants. The second part shows him playing a drum for a female dancer. In the third part, Han is surround by four female companions on a couch. In the fourth part, he sits in a chair, cross-legged with his robe unbuttoned, while five females play flute. In the left end, Han waves goodbye to his guests. The five parts are intriguingly separate by screens, whose real-world purpose is to partition large indoor space. Hence, each part can be regarded as a sub-scene of the long horizontal scene inside the huge mansion. Each sub-scene shows a mini event involving the same main character.

On a handscroll, the events seem to unfold successively to a viewer when they scan from one end to the other of the scroll. Yet, the viewer should not move themselves along the scroll to scan it, but rather move the picture. Wu Hung describes the proper and personal way of viewing a handscroll (Wu, 1996, pp. 59–61). When not in use, a handscroll is rolled up. On viewing, the spectator unrolls part of it, approximately one arm's length at a time. This length roughly defines the width of the viewing frame, and the spectator shifts this frame over the scroll every time by unrolling on one hand and rolling up on the other (see Figure **2**). This viewer-controlled unrolling process is strikingly similar to the act of panning the movie camera to track a moving subject, or to follow a set of indicative objects distributed across a scene (e.g., signs). The unrolling, like panning, is coordinated with the viewer's eyes and hands. When the viewer sees the main character in a sub-scene and wants to know what would happen to the character in the next, the viewer needs to continue with the tracking action on the scene. The viewer becomes interested in and even affected by how the scene would unfold. For example, a viewer of *The Night Entertainment of Han Xizai* seeing Han surrounded by female companions might feel concerned and could not wait tracking him in the next sub-scene to find out if there is any improper act. Emotional involvement is embodied in the eye-hand coordinated action of tracking.

Scroll-Driven Animations

The eye-hand coordinated action of tracking in the handscroll, other than resembling the act of panning the movie camera, also finds its digital counterpart in the act of scrolling content in the personal computer user interface. Content viewing applications, such as a web browser, in personal

Figure 2: The viewer's hands and eyes coordinate the panning frame of a handscroll painting.

computers typically allow users to scroll content vertically. In later versions of the MacOS system (e.g., Leopard or after) running on notebook computers, users can move fingers down (or up) on the touchpad to "unroll" the bottom (or up) of a web page. The scrolling direction is the same as the direction of the finger movement, which feels like moving a viewing camera above the web page. Some websites use a user-interface design pattern called "scroll-driven animations" to present "immersive" interfaces (Chow, 2025b), which enable users to move their fingers down (or up) on the touchpad to control the direction and speed of how the animated content dynamically plays out, having graphics moving in myriad ways on the page.[6] Like the handscroll having the whole scene painted on the canvas and waiting for the unrolling act, a scroll-driven animated web page has all its content prepared and scripted (using web technologies such as CSS and JS) in an exact sequence of mini events, many of which are 2D movements or transitions of graphics on the page, waiting for the user's scrolling action and playing out. A user in this kind of digital environment, like a handscroll beholder, sees a part of the narrative, feels interested in the animated scene, and adaptively moves the fingers to let the next part unfold.

2D Platformers and 3D Third-Person Games

The eye-hand coordinated action of tracking a subject is prevalent in certain video-game genres, such as side-scrolling platform games and third-person action-adventure games. In side-scrolling platform games, from the classic 2D platformer *Super Mario Bros.* (1985) to the recent cinematic 3D platformer *INSIDE* (2016), a player presses keys to control their character to move horizontally on a platform across the screen, revealing more of the game world as they progress. The interaction is the same as a user moving fingers on the touchpad to scroll content on a web page. One nuance is that a platform game maintains the player character in the center area of the screen with the platform and background settings sliding out of the screen, just like the mouse pointer staying on the screen with the content sliding out when a user scrolls on a web page. With the technique "parallax scrolling" where background image layers move past the screen more slowly than foreground image layers do, 2D side-scrolling can present an illusion of depth in a scene, looking much like a movie camera pan shot. Even in later 3D platformers like INSIDE, this aesthetics is intentionally retained. While a player focuses on moving their character to dodge moving obstacles, collect treasures, and advance on the platform, they trigger a sequence of events along their way in the horizontal game scene. This is like an animation of unfolding an eventful, long scene when a handscroll is unrolled.

With advances in computer graphics, some side-scrolling games have evolved into their third-person action-adventure versions. For example, *Zelda II: The Adventure of Link* (1987) is a classic side-scroller early in the Zelda series, and *The Legend of Zelda: Ocarina of Time* (1998) is first of the series that uses 3D computer graphics to render the third-person perspective, which is taken from a fixed distance behind and slightly above the player character. When a player controls their character moves in a 3D game space, the player character always stays in the center of the screen, and the game space "slides" along the character's running direction. Although the player character can move in any direction, an action-adventure game (e.g., *Prince of Persia 3D*), unlike open-world games (e.g., *Grand Theft Auto V*), typically stipulates a largely definite path in the 3D game world for the player to take challenges or treasures and then proceed toward a destination (e.g., being the Prince in *Prince of Persia 3D*, the player has to find and save the Princess kidnapped by the villain). The third-person action-adventure games are like 3D versions of the side-scrolling platform games. The players of either the third-person or the side-scrollers share similar experiences of feeling anxious or excited with the main characters and hence actively follow the in-game signs (e.g., *Stray*) to trigger the in-game events, playing out an eventful long scene at a certain game level.

4. MULTIDIMENSIONAL IMMERSIVE EXPERIENCE: CASE STUDIES

Brown and Cairns's study on gamers (2004) suggests that immersion is a graded experience progressing through degrees of engagement, starting from access, investment of time, effort, and attention, to emotional attachment and even empathy. Yet, immersive experience might not be linear. For instance, a person might only login a

[6] For example, see https://scroll-driven-animations.style/, https://highline.huffingtonpost.com/articles/en/poor-millennials/, or http://www.r2d3.us/visual-intro-to-machine-learning-part-1/

mobile game (e.g., Pokémon GO) and attend to their virtual creatures (e.g., giving treats) briefly once a day, but they would feel mad if their virtual creatures were gone (e.g., wrongly tapping the button to transfer them away). A player might spend consecutive days and nights to explore a vast virtual space in an adventure game (e.g., Black Myth Wukong), but once they beat the game, they might not care about how the story would end differently. A visitor to an interactive art gallery might be totally immersed and captivated in a vivid, elaborate, 360-degree projection (e.g., TeamLab works) and unaware of a phone call during the time of visiting, yet they would hurriedly check the missing call afterwards rather than rushing to another projection.

Instead of a linear progression, immersive experience is multi-dimensional, including two characteristics, namely distance to a space and emotional involvement in a scene. The first dimension, about distance to a space, includes two states, feeling adjacent to an extended space or feeling present in a separate space. The second dimension, about emotional involvement in a scene, includes two states, paying attention to changes or paying effort to track events. Many cases are prominent in mainly one state in one dimension, for example, 3D anamorphic billboards ("adjacent to an extended space"), immersive VR via a HMD ("present in another space"), dynamic wallpapers ("paying attention to changes"), or 3D third-person games ("tracking events"). Meanwhile, some exemplary cases span different states across multiple dimensions. They belong to the category of enduring immersion, which allows people to stay close to or sometimes step into another world, as well as intermittently follow and track happenings in that world at any time. Figure **3** shows a conceptual diagram of the two dimensions of immersive experience wherein exemplary cases populate. The following sections introduce and discuss them in relation to the two dimensions.

4.1. The Location-Based Mobile Game: Pokémon GO

With augmented reality (AR) technologies, a mobile or tablet screen can be seen as a portal into an alternate space that surrounds the user. For

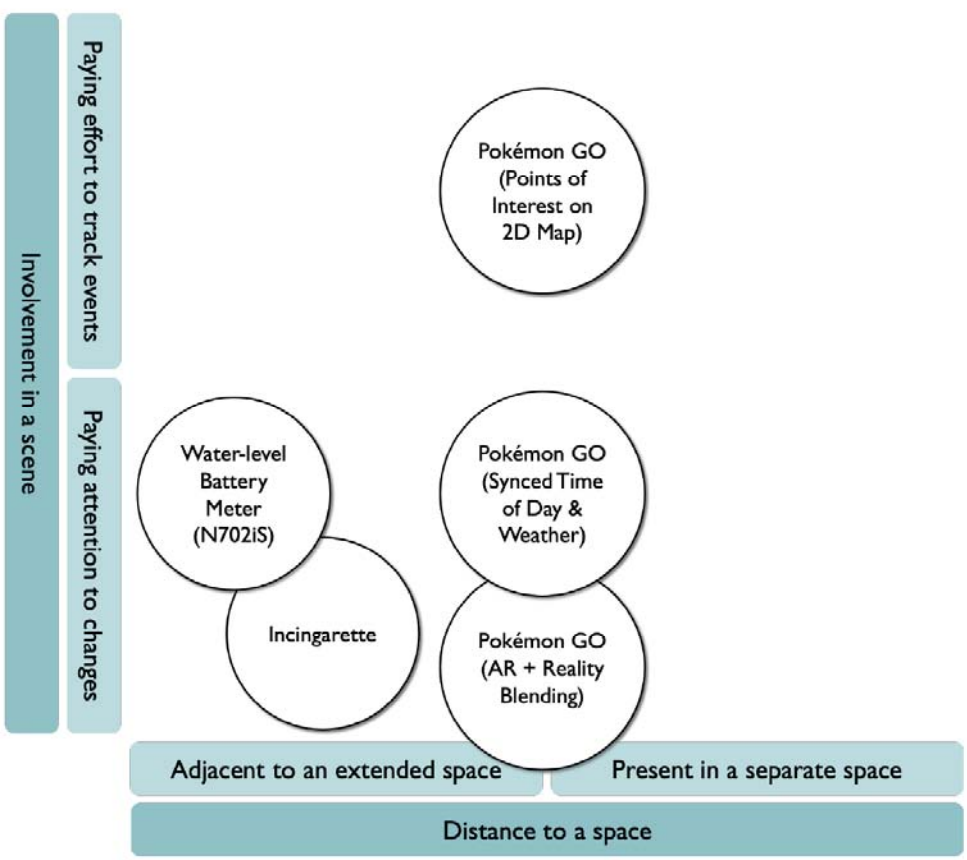

Figure 3: A conceptual diagram of the multidimensional immersive experience framework.

instance, *Pokémon GO* is a mobile game that asks players to catch and collect virtual creatures, called Pokémon, which populate the players' real-world surroundings. The game interface displays different views in different scenarios of play in order to immerse players in the imaginary Pokémon world. As the game is shown to have modest to significant effect in promoting physical activity (Khamzina *et al*., 2020), it can be argued that players are simultaneously absorbed in the imaginary world and motivated to explore in the real world.

AR View with Reality Blending: Adjacent to and Present in a Hybrid Space

The AR view uses the mobile phone cameras to capture live images of the physical setting and overlays 3D computer-generated images (CGIs) of a Pokémon. With built-in accelerometers and gyroscopes, the virtual creature is dynamically rendered in correct perspective in response to the mobile camera angle. On those mobile phones supporting the LiDAR technology, the game offers the reality-blending feature,[7] which computes the pixel-by-pixel depth of the Pokémon image against the actual depth of a point in the physical setting, and simulates object occlusion between the virtual and the physical. The virtual creature is perceptually blended in the physical environment. The mobile screen becomes a portal into a mixed reality wherein Pokémon exist. A player feels being adjacent to a 3D Pokémon through the mobile portal. Meanwhile, one can walk around in the physical space to see another side of the 3D Pokémon, like being present in a hybrid space. Hence, *Pokémon GO*'s AR experience situates between "adjacent to" and "present in" on the horizontal dimension of Figure **3**.

Third-Person View: Paying Attention to Changes

Pokémon GO provides a third-person view of the player's 3D character on a 2D road map corresponding to the player's real-world location. The sky above the road map changes to reflect the local time of day, shifting from a bright, daytime, through a magic hour, to a darker, nighttime. It might also rain, snow, or display moving curve lines to symbolize wind gusts, all according to the local weather forecast drawn from the Internet. The synchronized visualization of virtual time of day or weather according to the real-world information intriguingly features subtle, enduring changes in a virtual scene that not only draws the user/player's attention intermittently, but also gives the virtual world a sense of naturalness. Sometimes, a player moves in the real world for a distance and realizes a change in the local weather. Hence, *Pokémon GO*'s synced experience situates between "adjacent to" and "present in" as well as in "paying attention to changes" of Figure **3**.

Third-Person View: Paying Effort to Track Events

Instead of controlling the player character via a keyboard or a joypad, *Pokémon GO* players walk, run, or even ride a bicycle on a real-world walkway to move their characters and see the 2D road map slide on the mobile screen. Although the game allows players to move freely without setting any prescribed paths, which makes it more like an open-world game than an adventure game, the game developer does meticulously arrange various points of interest in the game world. For example, a player may see on the game map, which functions like a radar, showing that a specific Pokémon currently appears at a location within walking distance, some fixed points allowing players to receive items (i.e., PokéStop), or other fixed points where players can battle with other teams to take control (i.e., Gyms), meanwhile at designated time they may team up to defeat and catch a powerful Pokémon (i.e., Raids). All these special points of interest serve as sign posts that draw players' attention and motivate them to act accordingly in both the game world and the real world. Successfully catching a rare target definitely excites a player, while having it fled causes disappointment. Each player in the game experiences their own sequence of events while walking out their own path in the game world. The coordinated action of tracking the points of interest in the game is performed by moving the body rather than pressing a key (while playing typical computer games), which is an embodied act of tracking. *Pokémon GO*'s points-of-interest experience situates between "adjacent to" and "present in" as well as in "paying effort to track events" of Figure **3**.

4.2. The Mobile Phone N702iS

The mobile phone NEC FOMA N702iS (designed by Oki Sato and Takaya Fukumoto) features a "water-level" battery meter, which is displayed on the phone's screen as an interactive animation looking like real water.

[7] See https://nianticlabs.com/news/realityblending-announcement

Figure 4: The mobile phone NEC FOMA N702iS features a "water-level" battery meter, which is displayed on the phone's screen as an interactive animation looking like real water.

The Water-Level Interface: Adjacent to an Extended Space

When the user tilts the phone, the water flows to one side in a natural, realistic movement (see Figure **4**). The coupling of action and visual feedback makes the user feel like holding a phone filled with liquid. This interactive animation gives the user a feeling of "being adjacent to an extended space," wherein the screen opens a window into the phone, like the case of Dipal D1, and this window is within reach of a finger.

The Water-Level Interface: Paying Attention to Changes

Meanwhile, the phone also immerses it user in a state of "paying attention to a changing scene." Intriguingly, the water level slowly, enduringly descends because it actually indicates the battery level. While using the phone across the day, the user might peripherally see the water image and notice the level keeps descending. The user becomes aware of the remaining amount of battery power and assesses whether it is enough for the rest of the day. Unlike the dynamic wallpaper or *Pokémon GO*, this enduring change is not because of linking real-world environmental data, but instead anchoring the user's behavior. Chow and colleagues (2015) conduct user experience tests on an implementation of the interface. The qualitative findings from interviews inform that the dynamic interface engages participants' imagination (via the metaphorical projection between water and electricity) and emotion (anxiety due to not enough water) at different moments of use. The water-level interface experience situates in the "adjacent to" and "paying attention to changes" of Figure **3**.

4.3. Incingarette: A Smart Ashtray Container and a Digital Picture Frame

Incingarette (a portmanteau of "incinerator" and "cigarette") is an Internet of Things data visualization system that persuades people to reduce smoking by showing simulated outcomes in response to behaviour (Chow, 2021). The system includes a smart container for an ashtray together with a digital display encased in a physical picture frame (see Figure **5**), which can be used at home, in the office, or in public smoking cabins.

Figure 5: The Incingarette system includes a smart container for an ashtray in connection with a digital display encased in a physical picture frame.

Incingarette: Adjacent to an Extended Space

When a person uses the ashtray for smoking, the digital picture starts to be gradually covered with virtual dust and dirt (Figure **6**). This aims to create

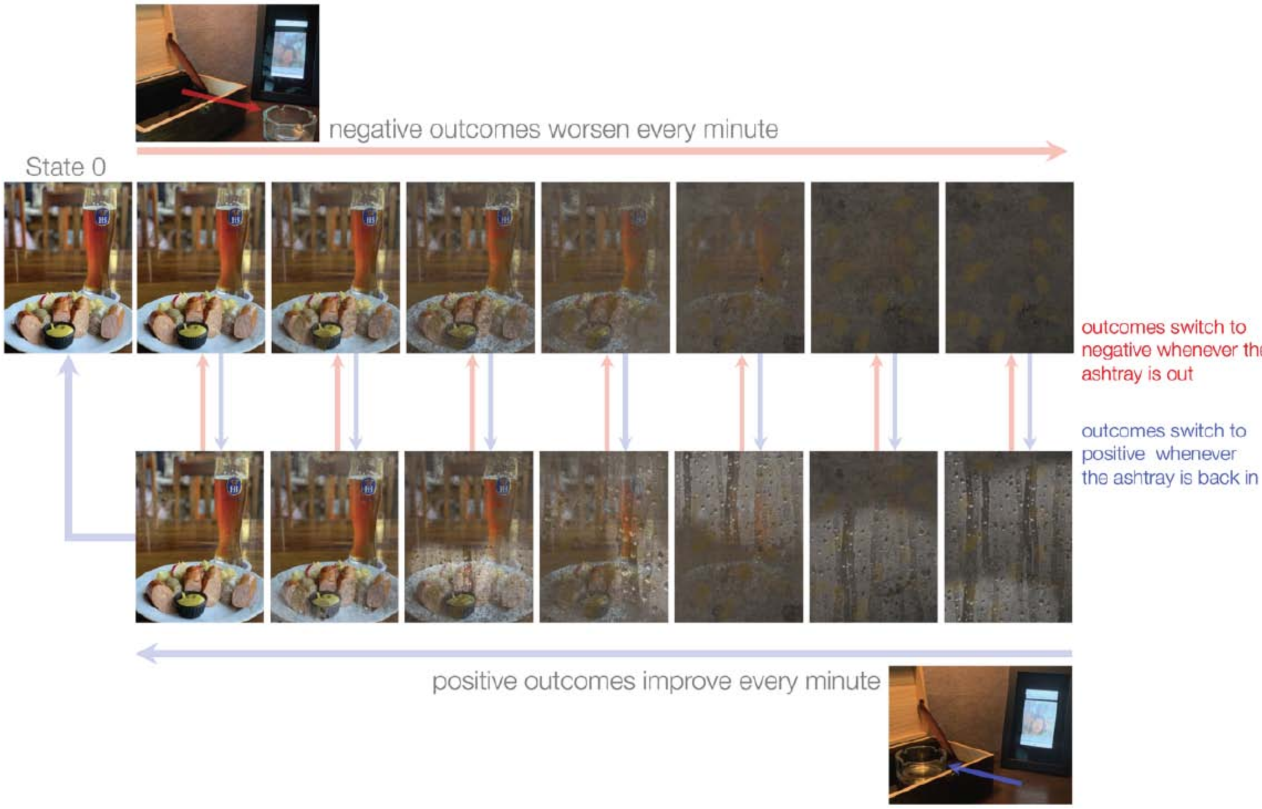

Figure 6: The sequence of images displayed on the picture frame of Incingarette. The upper row is negative outcomes. The lower row is positive outcomes. The blue arrows represent positive changes, while the red arrows represent negative changes.

an illusion of air pollutants from the cigarette falling on the screen. Like a 3D anamorphic billboard blending with the real building and the street to form a hybrid environment that surrounds the audience, the virtual dust and dirt of Incingarette blend with the physical setting to form an alternate smoking stage set. This corresponds to the immersive state of feeling "adjacent to an extended space," wherein the virtual dust and dirt on the screen look like almost allowing a finger to wipe off (that can be simulated on a touchscreen display). The smart container detects the use of the ashtray through its built-in weight force sensors and transmits data to the cloud server (MQTT server), which tracks the duration of a continuous session of use and maps longer duration to an image covered with thicker dust. The image is then shown on the digital display.

Incingarette: Paying Attention to Changes

In a continuous smoking session, the digital picture gets increasingly dusty. When the ashtray is returned to the container, virtual rain starts and slowly washes the dust away. This corresponds to an immersive state of "paying attention to a changing scene." With the digital picture showing one's favourite items or short-term goals, Incingarette projects possible outcomes of smoking – which suggest both a doubtful future if one continues with the habit and a more positive one for those who choose to stop smoking. The computer simulation of virtual dust covering the picture prompts the user's mental simulation of how smoking jeopardizes a favourable future, and how the mess can be undone by stopping the bad habit. Chow (2021) conducts a field trial of Incingarette with smoking participants over five consecutive days and results show that the repetitive, immersive experience enhances the intention and determination to reduce smoking. The Incingarette experience situates in the "adjacent to" and "paying attention to changes" of Figure **3**.

5. THE POST-REALITY FEEDBACK LOOP AND ETHICS OF ENDURING IMMERSION

Among the two characteristics of immersion, cases of immersive experiences that are prominent in either one dimension, for instance, immersive VR using HMDs or third-person games, belong to the category of immediate immersion, which is quick, concentrated, and momentary. People are transported and absorbed for a specific period of time, and then back to reality. The imaginary and the real world do not have much overlapping. On the other hand, cases that span different states across multiple dimensions are exemplars of enduring immersion. As seen in *Pokémon GO*, the water-level interface, and Incingarette, players or users can access to another world at any time within reach (e.g., tapping to catch a nearby Pokémon on the "radar" map, wiping off virtual dust on the digital picture) or sometimes step into it (e.g., walking on a real-world pathway to approach a Pokémon in the imaginary world). They may also intermittently pay attention to changes in another world (e.g., perceiving the amount of water remained "inside" the phone) or track and trigger events over there (e.g., joining the Raid battles one by one along a street). As people may vary their distance to a virtual space and involvement in a virtual scene at different times, enduring immersion allows blending of the imaginary and the real world in terms of not only spaces and places but also actions and happenings. Real-world actions and virtual happenings can be correlated. A *Pokémon GO* player's daily steps are tied with number of virtual Pokémon they caught and Raid battles they fought. The amount of virtual dust on the Incingarette picture depends on number of cigarettes the user has smoked.

When a person's real-world actions or settings are correlated with happenings in an imaginary world over time, they are able to imagine what they might act in the real world to achieve desired outcomes in the virtual one. The anchoring of virtual-world happenings to real-world states is enabled by computer simulation, such as computer animation simulating physical or natural phenomena of life (Darley, 2000, pp. 19-20; Manovich, 2001, p. 137), video games modeling real-world systems and their behaviors (Aarseth, 2004; Frasca, 2003), as well as generative AI technologies whose artificial neural networks parallel our biological brains.[8] Meanwhile, people's imagining of ways to achieving virtual-world outcomes is a kind of mental simulation taking place in the mind, which is defined as the imitation of real or hypothetical events including their processes and outcomes (Pham & Taylor, 1999; Taylor *et al*., 1998). Imagining experiencing certain events has proved to render imagined events subjectively more likely and influence intentions and even related behaviors (Anderson, 1983; Gregory *et al*., 1982; Koehler, 1991; Sherman *et al*., 1985). Mental simulation allows one to experience actions and emotions in a series of events with a causal relationship between them, like experiencing a fictional story (Oatley, 1999). When a person focuses attention on the imagery and emotion of a story, narrative transportation may take place, which also affects beliefs (Green, 2004; Green & Brock, 2000).

Chow (2023) identifies and theorizes the "post-reality feedback loop" that connects computer simulation and mental simulation (see Figure **7**). The post-reality feedback loop starts with capturing behavioral information that feeds computer simulation, followed by blending of simulated virtual content (i.e., VR/AR/MR content) in daily context, which prompts mental simulation in people's minds, leading to change or reinforcement of intention and hence influence back to the original behavior. Enduring immersion mobilizes this feedback loop through enabling the blends and correlations of the imaginary with the real. The cycle continues from the cognitive to the socio-technological level. People engage with various technologies (e.g., VR/AR/MR enhanced by generative AI) in daily contexts (e.g., routines, socials, entertainment), constituting the social and economic phenomena (e.g., huge investments from businesses and governments) that further motivate technological design and development (e.g., launches of new hardware and applications, construction of massive data centers), which then reinforces technology adoption (e.g., integration of AI and MR technologies in every facet of human activity) and the associated cultural perception (e.g., wearing AR glasses or even MR headsets in public or social settings).

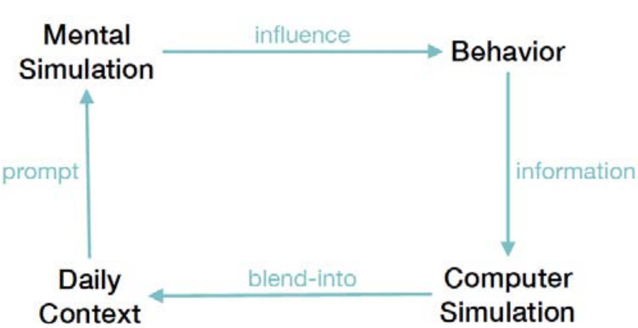

Figure 7: The post-reality feedback loop articulated by Chow (2023).

With the continuing advancements in AI and VR/AR/MR technologies, computer simulation may

[8] See https://www.kva.se/en/news/the-nobel-prize-in-physics-2024/

take a pivotal role in mobilizing the loop into our daily lives. The computer simulation system can pick up information on human behaviors and project different alternate realities to engage people and keep them interested. This is likely to be the primary objective of many service providers or technology enterprises, which are typically behind the computer simulation systems. They would like to collect more behavioral information from their users and turn their services into a more personalized, immersive experience that permeates their users' daily lives. These technologies and designs seem to ultimately keep the users in the feedback loop for these companies. While technologies relentlessly visualize alternate worlds and engage people in the feedback loop, ethical issues related to user agency and autonomy are paramount. Chow (2023) thus proposes that for the first basic level of agency, designers should make the mapping from behavioral information to simulated virtual content easy and clear for sense-making. In other words, the intervention strategies should be made crystal clear to users for the sake of transparency. Another level of agency is whether users have an autonomous choice to opt out from the feedback loop at any time, that is, becoming free from the intervention by computer simulation. This matches the call for the right to mental self-determination, which is the "right to create a thought, being in control of the decision-making process and free from cognitive interferences operated by computational manipulation" (Faraoni, 2023).

6. CONCLUSION AND DESIGN IMPLICATIONS

While enduring immersion is powerful in blending of the imaginary into the real, prompting mental simulation in people, and influencing their intentions and behaviors, designers and developers should always make the virtual-real correlations clear to the users. More importantly, Chow (2025a) further specifies that virtual-world events should sequentially unfold toward a direction in line with the user's real-world vision (p. 23). That is, a person who is engaged in the post-reality feedback loop can see their progress toward the same convergent point in both the imaginary and the real world. In enduring immersion, they are able to switch between staying adjacent to the virtual world or stepping into it at any time. They can intermittently pay attention to virtual-world changes or more actively trigger events over there. Virtual-world changes reflect real-world states, and virtual-world events indicate progress toward real-world goals.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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Not applicable.

DATA AVAILABILITY

Not applicable.

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