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'Real-time' virtual reality and the limits of immersion

RICHARD MISEK

What does virtual reality do best? Judging by its rapid uptake in fields including architectural visualization, surgical training, crime scene reconstruction, military simulation and, of course, gaming, virtual reality (VR) has proved to be a particularly effective tool for reconstructing and simulating physical spaces, as well as enabling a haptic engagement with them. It is telling that the most common descriptor for virtual reality is 'immersive', a term that highlights its spatial and experiential dimension. Writing in 1999, Jay David Bolter and Richard Grusin summarized the then prevailing view as follows:

> virtual reality is immersive, which means that it is a medium whose purpose is to disappear [...] As computer scientists themselves put it [...] the viewer should forget that she is in fact wearing a computer interface and accept the graphic image that it offers as her own visual world.[1]

1 Jay D. Bolter and Richard Grusin, *Remediation: Understanding New Media* (Cambridge, MA: MIT Press, 1999), p. 21.

Bolter and Grusin's extensive references to the professional and academic literature of the period highlight the degree to which spatial world-building was already underpinning assumptions about what the first generation of headset-based experiences did best. It remains so over 20 years later. Archetypal in this regard is gaming, currently the most popular VR consumer application. Of the 12 best-selling VR games on the 2018 Steam store, six were first-person shooter games and three were first-person fantasy adventures, genres that combine environmental and architectural visualization, battlefield simulation, and above all spatial exploration. In tandem with killing opponents, the goal of each of these

2 'Best of 2018 Virtual Reality: the top VR-only experiences as measured by gross revenue this year', <https://store. steampowered.com/sale/2018_ top_vr/> accessed 21 August 2020.

3 The term 'real-time VR' implicitly contrasts virtual environments that are responsive to users' movements with pre-rendered 360-degree video, which is typically linear and non-interactive but often still included within the broad category of 'virtual reality'.

games is to advance as far through their 3D environments as possible.[2] Many notable artistic uses of VR, from the visual defamiliarization of *In the Eyes of Animals* (Marshmallow Laser Feast, 2015) to the dense soundscapes of *Notes on Blindness: Into Darkness* (Arnaud Colinart, Amaury La Burthe, Peter Middleton, James Spinney, 2016) have also exploited its ability to generate vivid spatial experiences.

But what about time? How does the experience of temporality play out in VR? Virtual reality's focus on spatial experience typically leaves the temporality of a virtual environment to default to 'real time': time passes within it at the same rate as it does outside it. For example, in *Star Wars: Secrets of the Empire*, which I discuss below, participants undertake a spatially and temporally continuous journey, as if it were a single-shot film. Any other temporality would risk compromising VR's sense of immersion by drawing attention to its mediation. It is no coincidence that the fully interactive form of VR, the focus of this essay, is often called 'real-time VR'. The term refers specifically to the real-time rendering of a 3D environment that allows it to update in real time – that is, instantly – in response to users' movements.[3] At the same time, the immersion in a continuously unfolding space that real-time rendering makes possible has to date almost always entailed a 'real-time' user experience. Doubtless this is in part a by-product of the creators' desire to exploit VR's spatial and haptic potential, but it is also encouraged by the software used to create VR experiences.

Video editing software is structured around a timeline, which orders video clips created at different times and in different locations into a fixed duration (figure 1). Through the editing process the duration of the clips and the temporality that they collectively articulate can be readily manipulated; indeed, temporal manipulation is a key element of the editing process. By contrast, the 'game engines' typically used to create VR experiences are structured around a Euclidian space in which multiple assets (objects, characters, users' avatars) are placed in a spatial relationship with each other (figure 2). Although it is easy to create
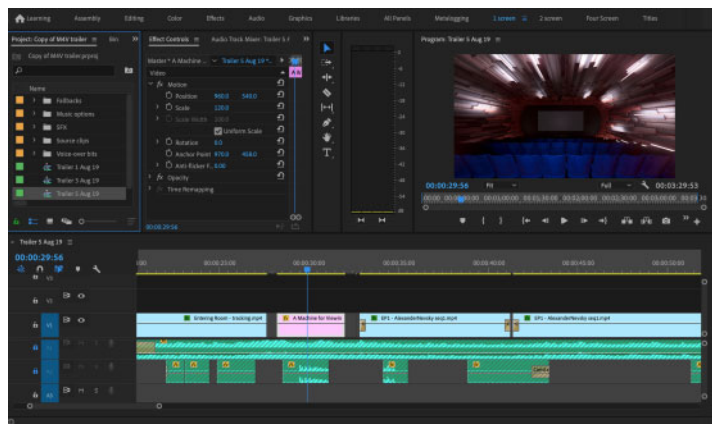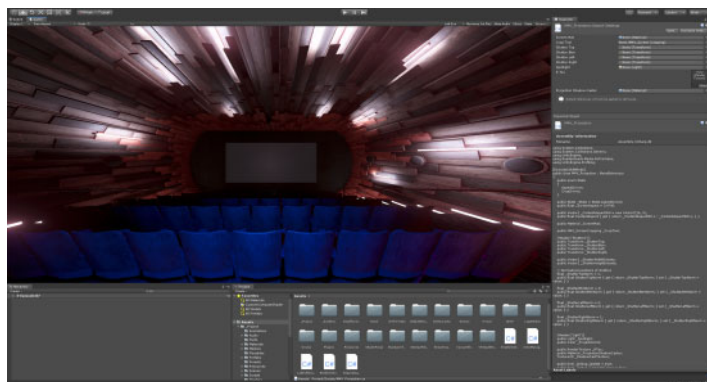

Fig. 1. The interface and linear editing timeline of Adobe Premiere. Image courtesy Richard Misek.

Fig. 2. The interface and 3D 'scene' view of the Unity game engine. Image courtesy Richard Misek.

spatial environments that bend the laws of physics, it is far harder to create environments whose temporality is malleable.

This essay emerges from a three-episode 'virtual reality video essay', *A Machine for Viewing* (2019), which I produced recently in collaboration with VR creator Oscar Raby and filmmaker Charlie Shackleton. The experience of working on this project brought into sometimes painful focus how well suited game engines are to world-building, and how ill suited they are to temporal manipulation. At a moment when uses of, and discussions around, VR remain dominated by the ideal of immersion, the explicit aim of our project was to use 'real-time VR' as a tool for immersion *and reflection*. Rather than creating an extensive space to be explored, we created a relatively small virtual cinema that would provide a familiar setting for a series of playful interactions with, and opportunities for reflecting on, 'cinematic' moving images. Over the course of the three episodes, participants manipulate the aspect ratios of various films shown in our 'VR cinema'; they experience a haptic interaction with the cinema screen; and they explore the perceptual differences between 3D space and the spherical flatness of 360-degree film. All episodes feature a voice-over narration that provides a degree of guidance and context for the participant's interactions. I cannot speak for my co-creators' use of voice-over, but my own choice to include it was a deliberately perverse one, aimed at creating a palpable tension between a linear narrative typical of cinema and a focus on interaction that was more typical of gaming. By providing an experience that at certain times felt like a typical documentary or essay film and at other times diverged drastically from linear narrative, my aim was to foster a dialogue between linear and interactive media, and to continue in a long tradition of attempts (such as those of the MIT Open Documentary Lab and the iDocs community) to hybridize the two.[4]

Unfortunately I did not realize just how much Unity (the software we used) resists attempts to constrain and shape duration. For example, although recent versions of Unity include a 'timeline' window, it is nothing like the top-level structuring tool so familiar to video editors.

4 For more details on the diverse projects carried out by these two groups, see <http://opendoclab. mit.edu/> and <i-docs.org> accessed 21 August 2020.

Rather it is an optional function that can be added to individual assets to cause them to perform a particular series of time-bound actions, such as moving along a specific path for a specific length of time. A Unity project may thus include multiple timelines, none of which are particularly important to shaping the overall temporal experience. Misled by the timeline function, I initially scripted a linear narrative interspersed with interactive sections, without fully appreciating that Unity is designed to deliver the opposite: an interactive environment interspersed with localized time-bound activities triggered by the user's movement through space. Through various workarounds, notably that of adding a timeline to a 3D asset and then populating it with audio clips, we were able to ensure particular lines of voiceover played at particular times. However, these workarounds also resulted in a complex network of connections between 3D assets, video clips, voice-over clips and interactive events, which meant that even the smallest alteration (such as cutting a line of voice-over) might have a ripple effect on the timing of the entire episode. Although my episode has the appearance of a linear video essay that features interactivity, under the surface its structure is stubbornly spatial.

Of course temporal manipulation is often unnecessary in VR; for the various forms of professional simulation listed above, real-time spatial experience is usually sufficient. For more creative applications of VR, however, the manipulation of temporality offers many potentially exciting avenues for experimentation. William Urrichio rightly observes that at present VR 'builds on the experiential narratives enabled by some game genres far more effectively than on the narrative structures inherited from cinema and literature'.[5] But that does not mean it cannot learn from the supple temporal manipulations that have long since been exploited to such great effect in other forms, including cinema and literature. Consumer VR launches from game genres so easily at least in part because it was developed as a tool for gaming.[6] As long as it remains restricted to creating the kind of immersive presence demanded by the mainstream gaming industry, it risks overlooking the creative power of temporal manipulation.[7]

I examine in this essay a number of VR works that engage creatively with temporality. In doing so I highlight the value of using VR to generate something like the opposite of Bolter and Grusin's definition of immersion: a sense of spatio-temporal 'outsideness' that involves a reflexive experience of looking in on a constructed world; an experience that could help uncover uses of VR who are not constrained by any established ideology of what it 'should' be. But first I provide a brief example of VR's default spatio-temporality. The VOID's *Star Wars: Secrets of the Empire* (2018) is a touring, location-based 'immersive virtual reality experience' that puts participants into the role of rebels infiltrating an Imperial base.[8] Participants are initially gathered into a small group and are each kitted out with a headset and backpack (in reality, a desktop computer strapped to their back that allows them to

5 William Urrichio, 'VR: between hope, hype and humbug', *Los Angeles Review of Books*, 25 June 2018, <https://lareviewofbooks.org/article/vr-between-hope-hype-and-humbug/#!> accessed 21 August 2020.

6 The HTC Vive headset was developed by consumer electronics manufacturer HTC in collaboration with videogame developer Valve. The Oculus Rift headset was developed by entrepreneur Palmer Luckey, whose initial Kickstarter campaign was titled 'Oculus Rift: step into the game', <https://www.kickstarter.com/projects/1523379957/oculus-rift-step-into-the-game> accessed 21 August 2020.

7 Especially influential in the writing of this essay has been Halil Deniz Tortum's seminal MA thesis, which critiques and seeks to provide an alternative to VR's emphasis on 'immediacy', *Embodied Montage: Reconsidering Immediacy in Virtual Reality* (Dissertation: MIT, 2016), <https://cmsw.mit.edu/deniz-tortum-embodied-montage-virtual-reality/> accessed 21 August 2020.

8 See *The VOID: A Virtual Reality Experience*, <https://www.thevoid.com> accessed 21 August 2020.

move around untethered). As they put on their headsets, the bare walls of an empty room transform into the interior of a spaceship, and the participants appear to each other as figures in stormtrooper uniforms, whose animation maps precisely onto their physical movement. As a working-through of VR's aspiration of spatial immersion, *Secrets of the Empire* is a remarkable achievement. The visual environment is meticulously modelled and rendered. The constraints of the physical location are ingeniously overcome within the virtual space: mid-sized rooms become flight decks, control rooms and walkways with panoramas across vast expanses of space. Meanwhile the path physically traced by participants through the installation is surreptitiously folded back on itself so that rooms already visited become whole new virtual spaces. The experience also hybridizes VR and cinema surprisingly effectively by combining the spatial immersion of VR with the fantasy of being 'in' a film, as a character in the diegesis.[9] Various avatars within the virtual environment speak to participants, thus strengthening their sense of being in a film while also subtly directing them through the spaces. While this work expands the cinematic experience of watching a *Star Wars* movie, it also reduces it. Participants are restricted to experiencing a single 20-minute scene that plays out in real time and in continuous space, and their main activities are confined to shooting and puzzle-solving. Just as the visual environment of *Secrets of the Empire* never escapes the iconography of the movie franchise from which it is derived, its interactivity never escapes the conventions of a first-person shooter. Nor does it need to. It is precisely the combination of familiar images and interactions that provides the most frictionless (and marketable) means of delivering the experience's main attraction: untethered physical movement through a simulacral virtual space.

Like most headset-based VR experiences, *Secrets of the Empire* plays out a spatial presumption that is already embedded in the commercial hardware and software used to create and experience VR. It is present, for example, in the design of the headset itself, whose lenses magnify a small rectangular LCD screen so that it extends beyond the user's field of vision. It is present, too, in the headset's default set-up, which even before any content has loaded translates the motion of the user's head into an equivalent movement in the virtual environment. This spatial presumption is further reinforced by the image that appears as soon as the VR headset senses a head inside it; the Oculus Rift, for example, presents a Cartesian grid extending in all directions along the x/z axes towards a horizon. Wait a few seconds, and you find yourself in the Oculus Store, which takes the form of an expansive modernist living room with picture windows looking out towards a blue-skied Californian horizon. Paradoxically one cannot walk through this space or do anything with the objects it contains; the business of loading content and managing one's account in fact happens on a series of flat panels that incongruously float in the middle of the living room, and whose layout looks not dissimilar from that of the Oculus website. Made to be looked at, the Oculus house

9 For a detailed discussion of how VR continues the immersive trajectory of cinema history, see Raqi Syed, 'Total cinema: or, "what is VR?"', *Senses of Cinema*, no. 90 (2019), <http://sensesofcinema.com/2019/feature-articles/total-cinema-or-what-is-vr/> accessed 21 August 2020. For an alternative perspective, which places VR outside the ocular-centric history of cinema, see Thomas Elsaesser, 'Pushing the contradictions of the digital: "virtual reality" and "interactive narrative" as oxymorons between narrative and gaming', *New Review of Film and Television Studies*, vol. 12, no. 3 (2014), pp. 295–311.

fulfils no function other than to showcase the headset's ability to display photorealist spaces.

The progression from Cartesian grid to 3D simulation mentioned above in turn replicates the process by which VR experiences are created. Both Unity and Unreal, the two programs most commonly used in VR production, initially also present creators with an empty space and an infinite Cartesian grid extending along the x/z axes towards a horizon. The interface pushes creators towards the spatial environments of 3D gaming: from populating the empty space with assets (objects, characters, buildings), through to defining a 'viewport' that establishes a first-person point of view, and setting up 'colliders' that prescribe what happens when the player's avatar hits an asset. Crucially the presumption of the software is that everything exists and happens in the same 3D space. Movement between discontinuous time-spaces, achievable so easily in cinema by means of a cut, necessitates the loading of a whole new 3D environment. As such it is typically restricted to occasional transitions between 'levels' of gameplay. The limitations of the software in this case are paralleled by those of the hardware: even if the software allowed instantaneous cutting from one 3D environment to another (for example, by means of a top-level timeline into which 'clips' of different immersive 3D spaces could be placed), it would still entail rendering the new 3D environment in a fraction of a second. This currently remains beyond the capability of even the specialized gaming PCs typically used to make and experience VR content. The spatial continuity implied by the game engine's interface, the real time of first-person gameplay, and the computer's real-time rendering are thus all symbiotic. As a result, creating anything that approaches the shaped temporal experience so easily facilitated by an editing timeline involves resorting to workarounds that resist the software, like those we used in *A Machine for Viewing*.

It is understandable that most instrumental uses of VR (such as those focused on training and education) depend on a sense of continuous spatio-temporality, experienced from a first-person point of view. It is less obvious, however, why more creative uses of VR (in game design or interactive documentary) should also restrict themselves to first-person experiences of continuous space-time – and yet usually they do. As if sensing the potential constraints of projecting users into vector-based environments, much recent commentary around VR has focused not on space but on the importance of users' bodies and on new technologies for interfacing with them.[10] As the recent development of headset-based motion sensors and eye-tracking has demonstrated, the potential for embodied interactivity to expand the functionality of VR is immense. At the same time, if engaging with users' bodies goes no further than giving them a virtual 'haptic' presence and agency that replicates how their bodies move and touch in physical space, then this will only perpetuate VR's spatial emphasis. Although enhanced forms of haptic interaction may allow VR to move away from the ocular-centric default of conventional cinema, this risks replacing it with a new default of

10 See, for example, Sita Popat, 'Missing in action: embodied experience and virtual reality', *Theatre Journal*, vol. 68, no. 3 (2016), pp. 357–78; Dan Golding, 'Far from paradise: the body, the apparatus and the image of contemporary virtual reality', *Convergence*, vol. 25, no. 2 (2017), pp. 340–53; Melanie Chan, 'Analysing movement, the body and immersion in virtual reality', *Refractory: A Journal of Entertainment Media*, no. 30 (2018), <https://refractory-journal.com/30-chan/> accessed 21 August 2020.

11 This contrasts with a tendency in 360-degree cinema towards a sense of disembodiment, insofar as in order to provide a full 360-degree panorama, a VR camera ideally needs to be placed on a tripod without an operator in sight – a set-up that comes with its own ethical problems. See Mandy Rose, 'Technologies of seeing and technologies of corporeality: currents in nonfiction virtual reality', *World Records*, vol. 1 (2019), <https://vols.worldrecordsjournal.org/01/11> accessed 20 August 2020.

12 Jean Mitry, *The Aesthetics and Psychology of the Cinema*, trans. Christopher King (Bloomington, IN: Indiana University Press, 1999), p. 76.

13 For a discussion of how 'appropriate distance' relates to VR, for example, see Kate Nash, 'Virtual reality witness: exploring the ethics of mediated presence', *Studies in Documentary Film*, vol. 12, no. 2 (2018), pp. 119–31.

14 Richard Wollheim, *Painting as Art* (London: Thames and Hudson, 1987), p. 21.

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corporeal centrism in which the user's body always forms the zero co-ordinates of a perspectival grid extending towards a horizon line.[11]

Something else is also needed for VR to escape its prison of Cartesian vectors. In my view that 'something else 'is an ability for VR to provide users with perspectives that are neither analogous to point-of-view shots nor anchored in the paradigm of embodied perception: perspectives, in other words, that allow for more reflexive, metaphoric and even abstract engagement with generated environments; perspectives that perhaps allow for ruptures in headset-based perception in the same way that Dziga Vertov's 'kino-eye' envisaged ruptures in cinematic spectatorship. Writing about film, Jean Mitry notes that 'Modern mathematics teaches us that an observer must necessarily stand in the $n+1$st dimension if he wishes to take in all the elements which make up a being or an object with n dimensions'.[12] Mitry elaborates this idea by invoking Edwin Abbot's book *Flatland*. The inhabitants of Flatland all take the form of a flat shape – a circle, square, triangle, and so on. But to see them for what they are, in their entirety, one cannot occupy the second dimension with them; one needs to look at them from the third dimension, from outside their spatial environment. By extension, Mitry notes, it is the experience of watching framed, flat films from the third dimension that allows us to apprehend and respond to them in their entirety. One might extend this observation by suggesting that the $n+1$, understood broadly as the sense of being 'outside' the spaces represented or simulated by a creative work, plays an essential role in aesthetic, critical, even empathetic engagement.[13] It makes possible what Richard Wollheim, writing about painting, referred to as the 'twofoldness' of artistic experience: a simultaneous attention to the 'content' of a work and the means by which this content has been generated.[14] But how can the immersive environments of VR provide the sense of an $n+1$ dimension?

Superhot (Piotr Iwanicki, 2016) provides a partial answer. Like *Secrets of the Empire* it is essentially a first-person shooter experience: as players move through different levels, stylised figures appear and shoot at them; each bullet leaves a red trail, inscribing its trajectory in space. The figures shoot so rapidly and from so many directions that the player can quickly become enmeshed in a lethal network of lines (figure 3). There is, however, a twist: stop moving, and time stops. The bullets freeze in mid-air; their red trails become functional, allowing the player to map the direction of the bullets' progress and plan how to move next. With a nod to the bullet-time of *The Matrix* (The Wachowskis, 1999), *Superhot* allows players to step back from immersive gameplay and regard it from an external perspective. This 'outside' is as much spatial as temporal. From outside the game's three dimensions, the bullet-trails become timelines. Each trail allows the player to extrapolate how far along its individual timeline a bullet has advanced, and to estimate how long they have left until it strikes them. Thus *Superhot* points to the possibility of seeing through, and playing with, the illusion of spatial immersion, by

Fig. 3. Temporally-inscribed space in (screenshot from) *Superhot* (Piotr Iwanicki, 2016).
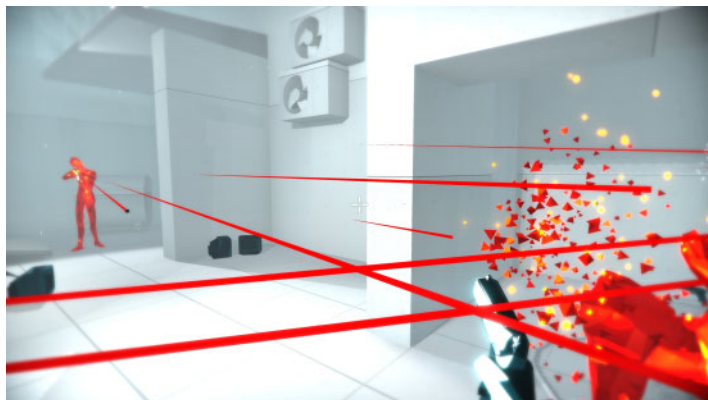
offering an escape from the spatio-temporality of gameplay and, in particular, by refusing to take Unity's presumption of 'real time' as a given. Yet despite this much celebrated divergence from gaming norms, *Superhot* still begins with, and plays out within, precisely the kind of simulacral 3D space that the game engine is designed to create. And as long as the user moves, it remains an archetypical first-person shooter experience.

Superhot is an example of the increasing, and genuinely astonishing, degree of immersion that VR has made possible over recent years. However, at a time when it is still in the process of defining itself, of exploring its potential and its limitations, it seems to me particularly important that VR creators should also be making works that look beyond immersion and instead investigate VR reflexively, as if from the outside. At one point, when I was participating in *Secrets of the Empire*, I lifted my headset and experienced a *Matrix*-like moment in which I saw the physical space of the installation. The computer panels were plywood walls, and R2D2 was a cardboard tube. Twenty metres away, through a doorway, a hunched cleaner mopped the floor of what had just (for me) been a platform floating far above the molten planet of Mustafar. This was the n+1 that the work itself was missing: a perceptual experience of being outside the virtual space, which transformed my understanding of the inside.

I conclude with two brief examples, each of which in its own way incorporates into its design a sense of n+1. Both, perhaps unsurprisingly, are by 'artists', not filmmakers, game designers or experience creators. The first is *Grisaille* (Teek Mach, 2019), labelled a 'virtual painting' by its creator.[15] *Grisaille* was made using Google's TiltBrush, a kind of immersive Photoshop that allows users to paint in three dimensions in-headset, within the virtual 3D space that they inhabit (figure 4).[16] Suspending users' marks in virtual space without any need for a supporting surface, TiltBrush exemplifies the potential for VR to move beyond spatial simulation, while still retaining traces of Earth-bound

15   See <https://teekmach.com/> last accessed 8 July 2019.

16   A disclaimer: the work has so far only been exhibited at Sundance Film Festival, and I have only seen documentation and read accounts of it. I have, however, used TiltBrush, so do at least have familiarity with the virtual space within which the artist worked.

17 Sarah A. Wolozin, 'Field notes: at Sundance, excitement, anxiety and an ecosystem in the making', *Immerse*, 8 March 2019, <https://immerse.news/field-notes-at-sundance-excitement-anxiety-and-an-ecosystem-in-the-making-e08d4b7300c8> accessed 21 August 2020.

space. For example, it opens in a dark forest (itself presumably created using TiltBrush), and though the intricately drawn trees disappear after a few seconds, a misty horizon remains visible at all times. The first part of *Grisaille* leaves this visual reminder of gravity completely behind: within its virtual environment there is no sign of the default TiltBrush horizon, just a series of body-shaped marks.[17] In the second part of the work, the participant takes off their headset and enters a separate room in which the artist is present; the artist then draws an outline of the user in TiltBrush, and places it into the virtual space that the participant has just experienced. This 'outside' part of the experience thus literally and figuratively frames the first, allowing participants to look at the virtual space on a flat monitor and to reflect on the process behind its creation.

It is notable that Mach's VR experience includes an element of live performance. If VR presents the user with a total environment, and if an artist wants to look beyond this total environment, physical space offers an obvious vantage point. It is no coincidence that, at the end of its two-year gestation, *A Machine for Viewing* ultimately also became a live performance. By installing the headset-based experience in a physical cinema and allowing an audience to watch the VR experience on an actual cinema screen, intercut with more traditional 'filmic' footage, we folded cinema and virtual reality within each other and turned them into each other's mirror. As a result the virtual reality experience becomes a playground for a series of experiments in cinematic viewing; the cinema audience in turn witnesses these experiments from the n+1 of the cinema space. In addition, at one point the participant is asked to take off their headset, and they too experience the audience's n+1 perspective. The moment at which one takes off a headset can be as meaningful as the moment one puts it on.

But is it possible to provide a reflexive 'outside' perspective on VR from within VR? Rachel Rossin's *Timescrubbing* (2016), a VR-based gallery installation, does so by rejecting spatial simulation entirely.

Fig. 4. Screenshot from *Grisaille* (Teek Mach, 2019).

As the participant walks around a corner of a gallery, a complex amalgam of 3D shapes variously explodes and reconstitutes itself as a single object (figure 5). One's initial instinct is to try to figure out what it is – a house perhaps, or a machine; in fact the 'object' in question is simply a combination of abstract 3D forms. After a while it becomes apparent that the image is less important than the interaction, which involves a causal relationship between one's movement and the animation: the object comes together as one approaches it and explodes as one backs away from it. The line traced by the participant's physical movement becomes a timeline, analogous to a play bar on a video, and by walking forwards and backwards they scrub along it. The discovery of this spatiotemporal transposition immediately complicates the sense that one is moving through virtual space. Instead one is moving through temporality, and not just temporality in general but the specific temporality of the script that is driving this interaction. It is as if one's body is moving forwards and backwards through a recursive loop of code, and experiencing not a space but a repeating timed procedure. Ultimately *Timescrubbing* reveals that the VR headset is just an interface. Although a user's movement usually triggers a corresponding change in position within a virtual space, this is simply a convention. It is even possible that in the future VR headsets may become tools for interactions that require no virtual spaces at all.

Deniz Tortum observes that '*Timescrubbing* allows conceptual abstract thought to become physical'.[18] 'Conceptual', 'abstract', 'thought': three terms that are commonplace in discourses around contemporary artistic practice but almost never used with reference to VR. By looking beyond immersive space, both *Grisaille* and *Timescrubbing* introduce VR to a space with which has rarely been associated – the space of reflection. In the Oculus Store, for example, the category 'Action and Adventure' currently includes almost 500 VR apps and games; the category 'Thought-Provoking Experiences' includes a mere 17.[19] Unless VR can find ways to stimulate different forms of engagement beyond the simple experience of spatial immersion, and unless it can in particular create more space for thought, its future as an artistic form may be limited, and it may struggle to find a space for itself as anything other than a tool for simulation.[20]

18 Tortum, *Embodied Montage*, p. 65.

19 'Rift store', *Oculus*, <https://www.oculus.com/experiences/rift> accessed 21 August 2020.

20 Even before COVID-19, the spatial hunger of physical VR installations (combined with the fact they could typically only be experienced by one user at a time) was already proving a logistical headache for many of the film festivals and galleries that hosted them. Now that haptic installations are – for the time being, at least – not possible, VR creators may need to focus more on experiences tailored to the constrained spaces of the home. I hope that this may, in turn, inspire new ways of reconciling VR's world-building tendency with the small crates of space within which it is now likely to be experienced.