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Into the *Vœrtex*: Case study of a stereoscopic abstract animation installation

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ABSTRACT

In Max Hattler's stereoscopic installation *Vœrtex* two-dimensional abstract animation is turned into immersive images with strong three-dimensional depth. Utilizing a two-

screen, semi-Cave Automatic Virtual Environment, *Værtex* creates a unique viewing experience for the viewer, a *hybrid* space situated halfway between immersion-in-abstraction and the real world of the gallery space, allowing the viewer to be in two spaces simultaneously. This article discusses the technical set-up, production processes and stereoscopic techniques, including binocular colour rivalry and depth displacements employed in *Værtex.* This is followed by a discussion of *Værtex* in relation to the concept of lucidity and an audience study into viewers' perception of the work. The hybrid set-up of *Værtex*, combining both stereoscopic and interactive visual texts, allows for a sense of creative inspiration and inquiry into the dreaming mind, and participants can actively choose to explore different aspects of their perception by oscillating between two divergent states: an immersive dream sensation and a sense of being anchored in the real world.

Keywords: stereoscopic vision, expanded stereoscopy, expanded animation, abstraction, lucidity, perception, immersion, Cave Automatic Virtual Environment

1 INTRODUCTION

Since the invention of the stereoscope by Charles Wheatstone in 1838, many different types of devices for displaying binocular images have been developed, through which we are able to perceive three-dimensional (3D) depth in flat images. Within abstract and experimental animation, a range of artists including Dwinell Grant, Oskar Fischinger, Hy Hirsch, Harry Smith and Sebastian Buerkner have experimented with stereoscopy. However, such abstract works have received little scholarly attention (Datta et al. 2016; Affleck and Kvan 2005).[1]

This article discusses Max Hattler's abstract animation piece *Vœrtex* (Figure 1), in which flat, two-dimensional (2D) source material is turned into an immersive stereoscopic art installation for a semi-Cave Automatic Virtual Environment (CAVE). A CAVE system can be regarded as a type of virtual reality (VR) interface as CAVE is defined as a spatially immersive display 'where images are projected on the walls, floor, and ceiling of a room that surrounds a viewer' (Stanney 2002: 18).[2] The principal viewer's head position is usually tracked by a head-tracking device to adjust the visual content to the viewing direction 'while other viewers "come along for the ride"' (Stanney 2002: 18).

Figure 1: A viewer interacting with the semi-CAVE set-up of *Vœrtex* (2021) during the *Art Machines: Past/Present* exhibition at Indra and Harry Banga Gallery, Hong Kong, Max Hattler (dir.), *Vœrtex*, 2021. Hong Kong. © Max Hattler.

In what follows, we provide a brief review of the technical set-up, production processes and stereoscopic techniques, including colour rivalry and depth displacements, employed in *Vœrtex*. The discussion and examination of the viewers' perception of the work are made through the lens of lucidity and its properties. We have conducted qualitative research through focus groups, individual interviews, open-ended questionnaires and direct observations to assess the perceptual responses and impacts of the stereoscopic effects generated in *Vœrtex*. Six semi-structured focus groups (with 31 participants) were conducted in 2021. These were supplemented by individual semi-structured interviews with participants who could not join the focus group discussions as planned. We also made some direct observations of participants' behaviour when they were experiencing the art installation, either individually or collectively (they were free to choose the way in which they wanted to experience it). Additionally, 23 questionnaires were collected from exhibition visitors. After the data collection, the focus group discussions were transcribed. Both data from the focus group study and questionnaires were then coded and analysed, informed by a review of relevant literature.

In the subsequent sections, the technical aspects of the installation will briefly be introduced, followed by an analysis of the work based on three different modes of manipulating viewers' perception: (1) the represented scene, (2) the display itself and (3) the interface between the display and the surrounding environment. This is followed by an evaluation of the data obtained from the audience studies. The concept of lucidity will

also be examined through viewers' perceptual responses to the various aspects: immersiveness and presence, awareness of the medium, interactivity and control, as well as the content and form of the visual texts found in *Vœrtex*.

2 TECHNICAL STRATEGIES AND PROCESSES

In *Vœrtex*, stereoscopic abstract animation is projected onto two screens, to be viewed with stereoscopic-active shutter glasses and a head-tracking device, which allows for three degrees of freedom by tracking the viewer's head rotation and translation. Instead of using a fully immersive technology such as a VR headset or a 'full' CAVE system with up to six screens, a semi-CAVE system consisting of two screens – a front screen and a seamlessly connected floor screen –was adopted in *Vœrtex*. A range of software was used in the production and display processes. The abstract image material and some of the sound were generated in vvvv,[3] while stereoscopic compositing, layering, and 3D displacements were created in Adobe After Effects.[4] An additional ambient soundscape was created in Ableton Live,[5] and for the presentation in the gallery space, the final rendered movie was mapped onto the inside of a virtual sphere in Unity.[6] The semi-CAVE two-screen set-up displays a cross-section of that sphere to the viewer.

The original 2D animation generated in vvvv is shifted horizontally in After Effects using displacement maps, which are derived from various colour and luminance information contained in the original 2D material. Through this process, the disparity range between left and right images is adjusted, with some visual elements pushed 'behind' the screen by shifting to the right, and other parts pushed into the foreground, closer to the audience, by shifting to the left. By rendering images with two camera views

for the left and right eyes in this way, 3D stereographic pairs with a strong sense of depth are generated from the flat, 2D source material.

3 ANALYSIS OF THE TECHNICAL ASPECT

James Jerome Gibson defined 'indirect perception' as the mediated perception of a virtual scene that is represented by retinal pictures, neural pictures, or mental pictures, in opposition to our unmediated 'direct perception' of the real world through a process of information pickup that involves the action of looking around in the environment (Gibson 1986: 139). Indirect perception exists on a continuum, from the simplest drawn sketch to the most complex photo-realistic VR experience (Sedgwick 2003). The abstract virtual space of *Værtex* sits in between these two extremes, and it can be evaluated according to Sedgwick's three modes of manipulation for different kinds of indirect perception (2003: 63).

3.1 The represented scene

The first mode of manipulation of viewers' perception comes from 'the kind of information that is provided to specify the represented scene' (Sedgwick 2003: 63). In our case, this refers to the *Værtex* video itself.

3.1.1 Depth perception and depth cues

Depth perception refers to our visual ability to perceive things in three dimensions and to judge how far away objects are (Kleiber and Winkelholz 2008). Different types of visual depth cues, including monocular, binocular and proprioceptive depth cues, provide different types of cues for the distance of an object from the observer and affect the level of depth perception (for more details, see Kuchelmeister 2020: 57–61; Solso 1994: 161–76, Fuchs et al. 2011b). The 2D images can contain many monocular (or pictorial) depth

cues of the depicted 3D structures, such as light and shadows, apparent size, perspective, texture cues, interposition or variation of visibility. Yet stereoscopic 3D images can 'provide subjectively more compelling depth information than images containing only monocular cues' (Yamashita de Moura 2018: 7). The binocular depth cues of convergence and disparity are crucial in enabling the viewer to perceive visual depth in a scene.[7] They afford the illusion of 3D depth from 2D images, each viewed by one eye (Howard and Rogers 1996). Through the manipulation of convergence and binocular disparity, three kinds of stereo effects can be achieved in stereoscopic images:

> Either the image remains within the boundaries of ordinary cinema as a kind of flat haut-relief, poised somewhere within the plane of the reflecting screen. Or the image plunges deep inside the screen, drawing the spectator along into unprecedented depths. Or, lastly (and this is the most astonishing effect) – the image, palpably three-dimensional, 'tumbles out' of the screen into the auditorium.
>
> (Eisenstein 2013: 22)

In *Vœrtex*, the manipulation of stereoscopic depth cues leads to graphic elements protruding out of and into the screen space. In addition, since *Vœrtex* is an abstract piece, viewers' perception of depth comes not only from binocular depth cues but also from the abstract nature of the work itself. As art philosophers such as Clement Greenberg and Michael Fried pointed out, 2D abstract painting can elicit a perception of depth (Fried 1998: 233; Greenberg 1993; Newall 2011). For Richard Wollheim (1987), the experience of viewing abstract painting requires both an awareness of the marked surface and the depth.

3.1.2 Binocular and colour rivalry

Stereoscopic fusion of left and right images in *Vœrtex* assures that the illusion of a coherent 3D space remains intact. However, within this stereoscopically fused space, some binocular rivalry effects, such as subtle colour rivalry based on colour differences between left and right eye images, are used (Figure 2). Colour rivalry adds a luminous lustre to the image, which creates a more intense and unusual viewing experience. Strong binocular rivalry is used sparingly and always only on layers that are in an otherwise stereoscopically fused space.

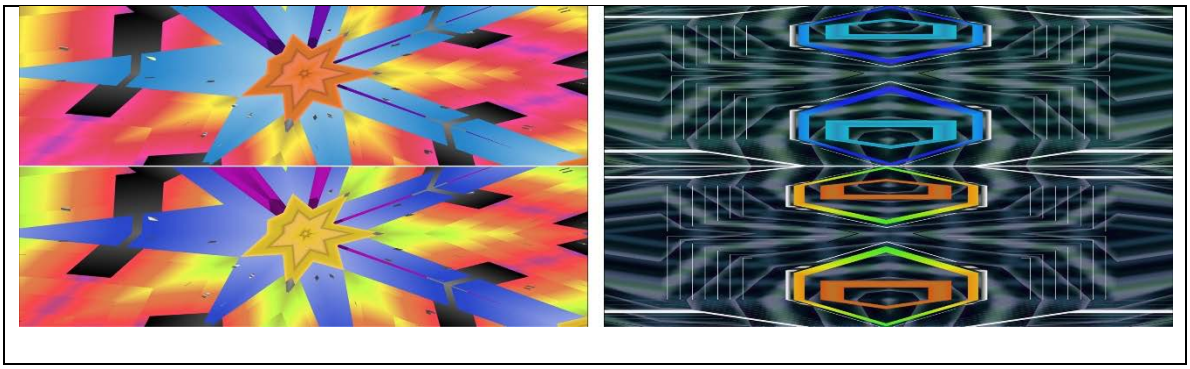

Figure 2: Stereo pairs with colour rivalry, in top/bottom format, Max Hattler (dir.), *Vœrtex*, 2021. Hong Kong. © Max Hattler.

3.1.3 Colours, textures and layers

The aim of *Vœrtex* was to take the viewer out of the everyday by placing them inside of an abstract space of colour, shape, form and sound, while simultaneously being firmly located within the real, physical gallery space. Aesthetically, the visual space in *Vœrtex* is loosely inspired by the patterns and colours of TV test cards. Hard shapes and clean colours create sharply defined depth, while the more muted colours and softer textures of the background layers allow for softer, more organic depth displacements. The layering of images creates unusual depth perceptions, where visual elements from different layers

permeate and intersect each other or become ‘windows’ into other layers, leading to convoluted and at times paradoxical depth arrangements.

3.1.4 *Sound*

The surround soundtrack of *Vœrtex* helps to anchor the piece, and to bring the viewer into it. It comprises an ambient soundscape composed to picture and an additional super-synchronized ‘optical’ soundtrack, which was generated by digitally ‘reading’ the colour values of lines of pixels in the image and translating that information into sound. This direct linkage between image and sound creates a ‘synaesthetic’ connection between what is heard and what is seen, underlining the sense of immersion. There is an element of spatialized immersion in the sound as well. As the viewer navigates around the screen space, they will move closer or further from the different speakers, which are positioned in front, left and right next to the wall screen and behind the viewer, left and right behind the floor screen, with an additional subwoofer behind the wall screen.

3.2 The display itself

The second mode of manipulation of viewers’ perception is ‘the kind of information available to specify the display itself’ (Sedgwick 2003: 63). With the semi-CAVE set-up, the visual display consists of two adjacent screens on the wall and floor, which together create a seamless 3D viewing area (Figure 3).

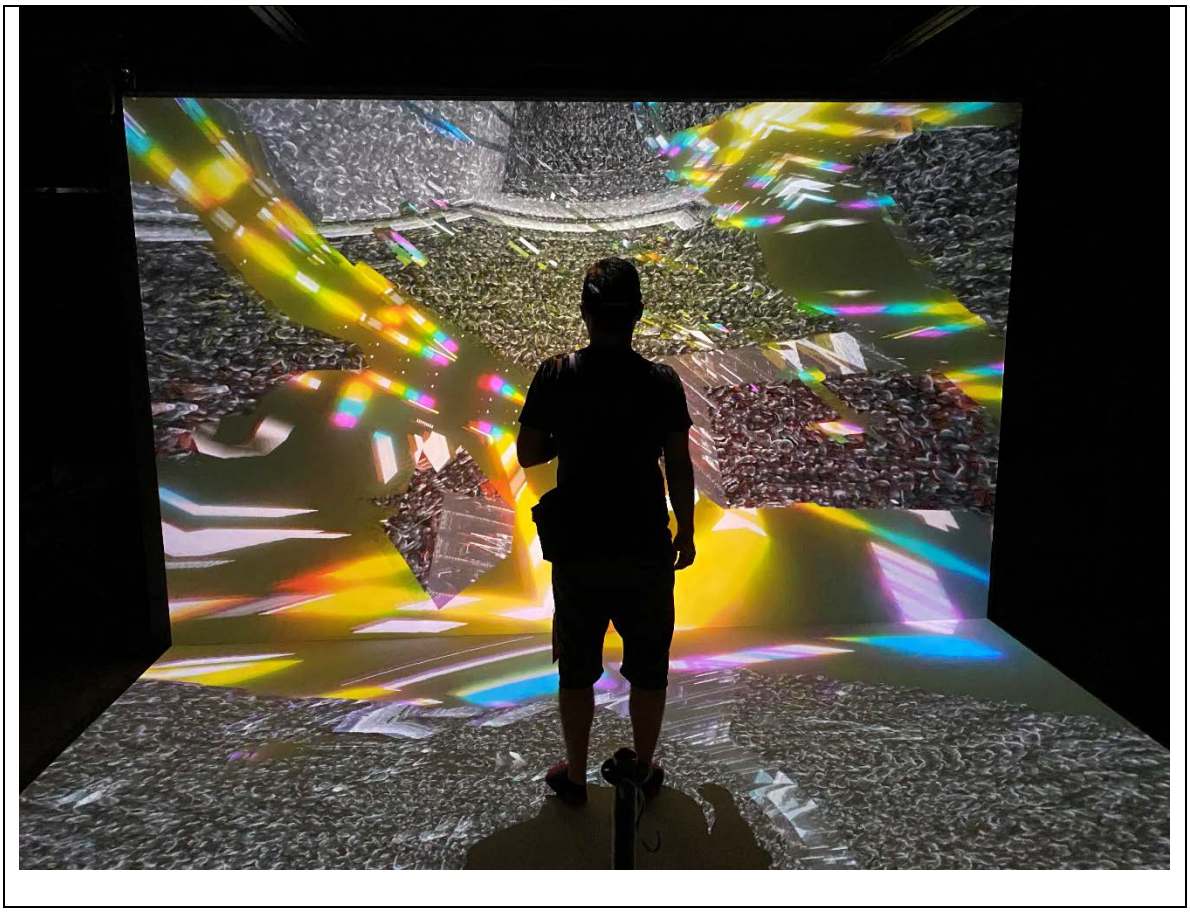

Figure 3: The semi-CAVE set-up of *Vœrtex* allows the viewer to enter the screen space, with the two screens (on the wall and the floor) creating a seamless 3D space, Max Hattler (dir.), *Vœrtex*, 2021. Hong Kong. © Max Hattler.

3.2.1 Entering the screen space

The semi-CAVE allows the viewer to enter the screen space. For the viewer who wears a head-tracking device and 3D glasses, the two-screen set-up creates a seamless 3D space, where the border between the two screens is all but imperceptible. This immerses the viewer in an imaginary world that extends in front of and below them, similar to the experience of wearing a VR headset. However, in contrast to VR, the gallery space is still fully visible to the viewer. As such, the semi-CAVE allows for the simultaneous

experience of two different 'realities' – real space and projected space – with conflicting spatial perceptions. This lets participants preserve their sense of presence (a sense of being in a place), both in the physical space of the gallery and in the stereoscopically created screen space of the piece. However, this presence is undermined or subverted to some extent through the deliberate use of abstraction: the viewer has a sense of presence, but since the abstract shapes and forms do not correspond to a figurative-representational space but an abstracted one, the viewer might feel somewhat dislocated or disorientated.

3.3 The interface between display and surrounding environment

The third mode of manipulation of viewers' perception refers to 'the interface between the display and the surrounding environment of the observer' (Sedgwick 2003: 63).

3.3.1 Immersion, field of view and frame of reference

Besides stereoscopic depth cues, immersion is another significant factor which can improve human perception of the presented components and environments (Wichansky 1991; Pausch et al. 1997; Yamashita de Moura 2018). Immersive media tend to conceal elements that threaten the sense of realness of the presented imaginary world, such as the frame of the display screen (Jones 2018: 39). In VR and similarly in a full CAVE set-up with up to six screens, the viewer's field of view is very wide, with no apparent screen surface or frame. While this aids immersion, it also leads to the viewer losing their frame of reference to the world outside of the stereoscopic image space (Kuchelmeister 2020: 140). In the case of *Vœrtex*, the use of a semi-CAVE setting was adopted in order to maintain the viewer's connection to the real world. Here, with the field of view limited to two screens only, the frame of reference to the world outside remains available and easily accessible. While less immersive, and with a smaller field of view than VR, *Vœrtex* still

goes well beyond the constraints of the single screen. Ultimately, the viewing experience of *Vœrtex* is intentionally designed to be that of a *hybrid* space, composed of the stereoscopic abstract image space, and the real physical space that surrounds it, allowing the viewer to be in two spaces simultaneously.

4 ANALYSIS OF THE PERCEIVED EXPERIENCE

4.1 A quest for lucidity in the semi-CAVE setting of *Vœrtex*

The experience of VR (and CAVE) is regarded as similar to that of lucid dreaming, since viewers are fully immersed in a realistic, interactive multisensory environment, while simultaneously being aware of the unreal-ness of the experience. This connection between VR and lucid dreaming is also evidenced in the use of VR in training human subjects to increase their level of lucidity when dreaming (Gott et al. 2021). VR can be utilized to practice lucidity as it can provide 'dream-like' experiences in waking life which enhance the reality check technique through which participants can critically question whether what they are experiencing is real or a dream state (Gott et al. 2021; Carr 2021). In a lucid dream, the dreamer knows they are dreaming rather than experiencing reality, allowing them to consciously influence the content and direction of their dreams (LaBerge 1985; Walker 2017). In other words, lucid dreams are 'dreams in which we know we are dreaming' (Van Eeden quoted in Bogzaran 2003: 30). In her article 'Virtual lucidity: A media archaeology of dream hacking wearables', Aleena Chia (2018) quotes lucid dreaming tools developer Jay Mutzafi to point to the connection between VR and lucid dreaming:

> [L]ucid dreaming, once it's stable is like virtual reality from fifty years into the future where you have photorealistic, full immersion, full bodysuit that you can't even feel,

> [and] mind control to some degree over the environment. It's absolutely remarkable and you can do anything from flying, to talk to dead relatives. Your imagination is the limit.
>
> (Mutzafi 2015 quoted in Chia 2018: 1)

The virtual world is 'an imaginary space often manifested through a medium' (Sherman 2019: 8) through which participants are presented with different types of visual texts or collections of objects in a space within a simulation. In Figure 4, several types of such virtual media or environments, ranging from the most natural to the comparatively more artificial, programmed or automated environments, are listed as examples.

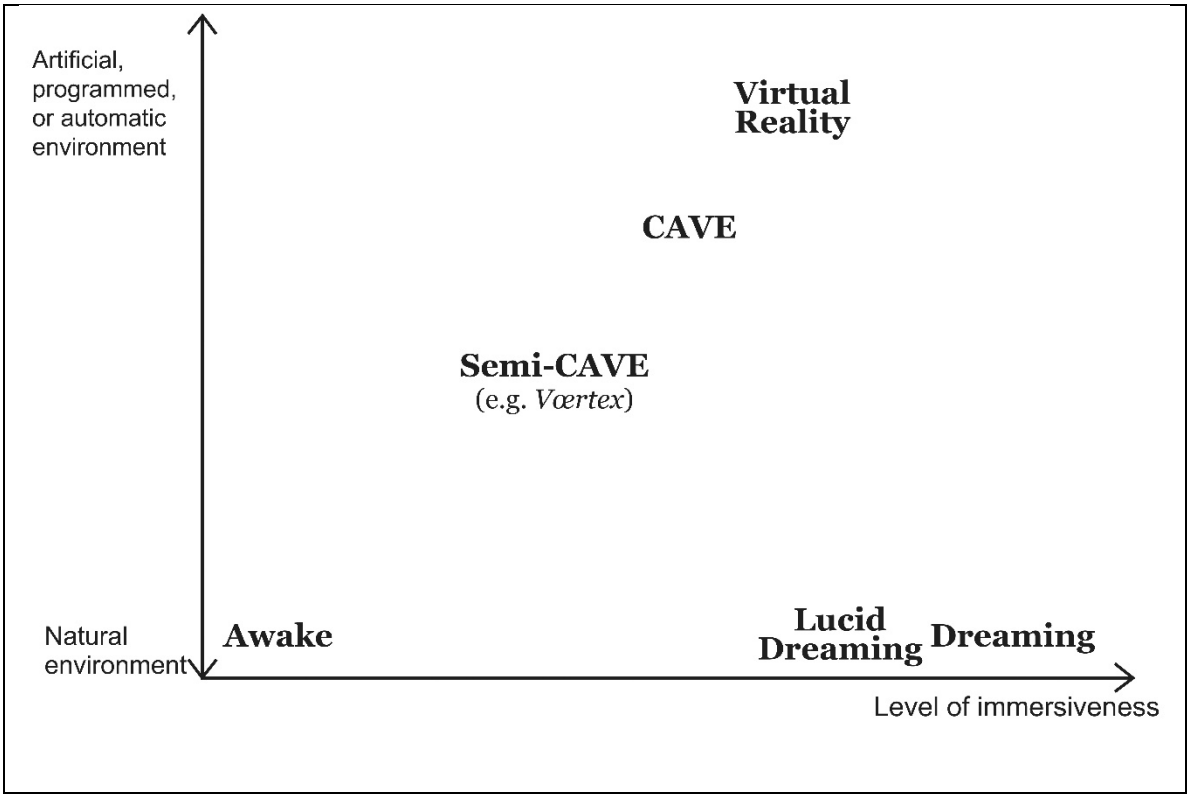

Figure 4. Comparison of various types of virtual media or environments. Image created by the authors. © Max Hattler and Terrie Man-Chi Cheung.

Dreaming and lucid dreaming are the most natural and immersive environments, whereas VR, CAVE and semi-CAVE are artificial media with different levels of

immersive technology. The semi-CAVE provides both an artificial environment (the immersive screen space) and a natural environment (the surrounding environment outside of the screens). The level of immersiveness in the semi-CAVE is comparatively lower than in VR and lucid dreaming, resulting in higher viewer attention to 'real' reality. The semi-CAVE can thus foster a state similar to lucid dreaming, i.e., a 'dissociated state with aspects of waking and dreaming combined' (Voss et al. 2009: 1191). According to Voss et al., such a state refers on the one hand to the 'wake-like reflective awareness and agentive control experienced' (2009: 1191). In the case of *Vœrtex*, this can be triggered by the surrounding real environment outside of the screen space. On the other hand, there is the aspect of 'hallucinatory dream activity' (Voss et al. 2009: 1191), which in our case is brought about mainly by the visual imagery displayed across the two screens, and the viewer's interaction with it.

In the following discussion, lucidity in *Vœrtex* will be examined in terms of immersiveness and presence, awareness of the medium, interactivity and control, as well as form and content of the piece. The investigation of these aspects is informed by the qualitative data derived from our audience study into the viewers' perception of the work.

4.1.1 Immersiveness and presence

'Immersion and interaction are the two key words of virtual reality' (Fuchs et al. 2011a: 8).[8] According to Mel Slater, immersion differs from presence in that it refers to 'what the technology delivers from an objective point of view', whilst presence is 'a human reaction to immersion' (2003: n.pag.). In our audience study of *Vœrtex*, some participants expressed responses such as joy, surprise, nervousness, feeling excited, numb or tired. However, such kinds of involvement, interest or emotional response cannot be considered

a sign of presence (Slater 2003). To achieve total presence, Slater contends that we would need to construct a system that has such a high fidelity that it becomes indistinguishable from reality. Since *Værtex* is an interactive virtual environment which displays *abstract* animation that is designed to be in opposition to representational reality, participants found the experience 'unreal', 'futuristic' or 'more abstract than real' as they could not recognize any shapes or forms that corresponded to their lived, real-world experience. As such, most of the participants found it difficult to suspend disbelief and escape to a mediated world. Only a few participants responded in the questionnaires that they felt like floating or 'flying in a virtual space', which made them feel like 'being inside of a dream' – albeit an abstract one.

4.1.2 Awareness or ignorance of the medium

To achieve suspension of disbelief, 'to give in to a simulation – to ignore its medium or the interface' (Cruz-Neira et al. 1992: 65), is considered a fundamental component in the effective use of a VR interface. By weakening the viewers' awareness of the medium during their exploration in a virtual environment, their sense of presence will be increased. Participants could actively choose to ignore the medium; the medium might provide participants with an illusion of non-mediation (Lombard and Ditton 1997: 16-17), or the participants might even perceptually and psychologically fail to perceive the existence of the medium (Ijsselsteijn 2005: 8). However, such an illusion of non-mediation is hard to find in the experience of *Værtex*, since participants will be acutely aware of the medium in a semi-CAVE setting where they can see the edges of the two screens and the significant difference between the technological setting and the outside environment.

First, many participants of *Værtex* confirmed that they knew very clearly that they were engaged in a mediated experience. This is similar to lucidity in a lucid dream, where dreamers are aware of their state of dreaming, and the mediated experience is known, which will weaken presence. Lucid dreamers remind themselves that 'this is only a dream'.

Second, the willingness to suspend disbelief probably varies across individuals, and within the same individuals across time, and is determined by the characteristics of media form and content (Lombard and Ditton 1997: 36–37). This usually depends on the individual user's knowledge of and prior experience with the medium in question (Lombard and Ditton 1997: 36). In our questionnaires, both for participants of focus group discussions and for ordinary exhibition visitors, we asked questions concerning their general knowledge and prior experience of the stereoscopic 3D medium, as well as participants' estimation of their own experience with and knowledge of art. The replies showed that most participants (55.6 per cent of focus group participants and 52 per cent of ordinary visitors) did not have any prior experience with stereoscopic films or artworks before *Værtex.* A few replies in the questionnaires revealed that they did not understand the meaning of stereoscopic visual effects. Both types of visitors replied that their knowledge of art is at a 'medium' level (76.7 per cent of focus group participants and 52.6 per cent of ordinary visitors), with the focus group participants reporting a higher rate of art exhibition visits and art training backgrounds. As such, the focus group participants curiously engaged in discussing the artist's rationale behind the implementation of the work. However, since many of them did not have any prior experience of viewing stereoscopic works, this might have created an obstacle to

suspending disbelief in the media experience.[9] A lack of prior experience and unfamiliarity is likely to discourage a strong sense of presence in the viewer (see Held and Durlach 1992), but continued experience may either increase or decrease such sense of presence (Lombard and Ditton 1997: 37). Yet in this study we could not determine any clear correlation between the factors of prior experience and knowledge, sense of presence and suspension of disbelief.

Third, the hybrid semi-CAVE interface of *Værtex* allows and encourages a simultaneous awareness of *both*, the virtual world displayed on the screens and the real world outside of them. In the relatively non-intrusive (semi-)CAVE, when compared to the restrictive locked-in sensory experience mediated by a VR headset, 'the viewer is free to move at will, secure in the awareness of the real, as well as the virtual, aspects of the environment' (Cruz-Neira et al. 1992: 68).[10] Some focus group participants, however, noted that they found this spatial hybridity disruptive to their sense of immersion in the piece.

4.1.3 Interactivity, control and performativity

As mentioned, the dreamer in a lucid dream is aware that they are dreaming and can often influence or control the content or direction of the dream (LaBerge 1985). The viewer of *Værtex* can similarly interact, in a limited fashion, with the work through their movements as the head-tracking device maintains a viewer-centred perspective. At the same time, the participant can observe their own or the other participants' actions, movements and interactions within this hybrid environment. The semi-CAVE of *Værtex* allows multiple users to simultaneously benefit from the experience. However, the ideal and interactively adjusting 3D perspective only works for the single viewer who wears

the head tracker. Other participants, wearing 3D glasses but no head tracker, can view the contents from the perspective of this participant, and a suspension of disbelief becomes more difficult for them (see also Cruz-Neira et al. 1992: 65).

Several participants of the audience study mentioned that they still found *Vœrtex* fun and engaging, even when they were not wearing the head-tracking device. Other respondents pointed towards a different type of performativity, noting that the interactive viewing experience with more than one participant was enjoyable and surprising, as they could watch and observe how others played with the piece – in ways not necessarily intended by the artist – where all participants ended up becoming a performative part of the artwork (see Figure 5). This can be understood as a type of performativity in terms of other participants' gazes and one's own gaze, where participants' bodies and movements are physically visible for other people to see. To the participants themselves, their gaze and perception are also a way of acting if we follow Maurice Merleau-Ponty's (1962: 244) notion of perception in phenomenology.[11]

Figure 5. A group of participants are interacting with *Vœrtex*, while simultaneously engaging in a type of performativity by observing each other's behaviour, Max Hattler (dir.), *Vœrtex*, 2021. Hong Kong. © Max Hattler.

4.2 Visual form and content

4.2.1 Combining abstraction and representational images?

While most research participants identified *Vœrtex*'s imagery in terms of geometric abstraction, a few responded that they recognized representational or realistic images in the piece.[12] For instance, some viewers subjectively perceived elements such as a river, a house, an old temple, a man, as well as geometric shapes and forms conjuring early video games and television test screens. As mentioned previously, the abstract visual aesthetic of the work is indeed influenced by TV test patterns and colour bars. However, this imagery is essentially liberated from icons and symbols into non-representational articulations of shape and form, colour, movement and time, where the focus lies on presenting spectators with extraordinary perceptions or unusual experiences.

4.2.2 Invoking dreams and hallucinations

Film theorists such as Michael Betancourt (2007: 59) and Paul Taberham (2018: 174) have pointed to the overlaps between hallucinations and visual music or abstract film.[13] *Vœrtex* can be understood in this light, as it employs abstract imagery, symmetries and kaleidoscopic patterns, as well as synchronized sound to conjure synaesthetic, hallucinatory, illusory or dream-like altered mental states (see also Sitney 2002: 38; Taberham 2018: 16). Several participants of the audience study noted that the work provided them with the sensation of 'being inside a dream, with a floating feeling',

especially when standing on top of the floor screen, or as if they were ‘interacting with those visual elements on the screens, just like being in a dream or fantasy’, while at the same still feeling grounded in the real world.[14] The ‘optical’ soundtrack in *Vœrtex* creates an extremely tight synchronization with the visual components for an enhanced sense of synaesthetic immersion. Some participants remarked that they felt as if they were ‘in a kaleidoscope’ and became emotionally excited whenever the visual patterns and the synchronized sound intensified. Pointing to the direct relationship between sound and image, viewers mentioned that ‘the pace of the sound is in line with the visuals’, that the sound ‘went with the patterns’, that ‘when the colour floats up, the music goes higher pitch’ or that ‘when the music was playing intensively, the pattern also moves vigorously’. However, the audience study also revealed that a number of visitors did not actively pay attention to the audio elements or found the exhibition environment too distracting for them to fully engage with *Vœrtex*’s soundscape.

5 CONCLUSION AND FUTURE PERSPECTIVES

Vœrtex provides a unique viewing experience for participants, with strong 3D depth created from flat, 2D source material, and experimental uses of stereoscopy such as binocular colour rivalry. This aesthetic and its implementation through a semi-CAVE are different from other common virtual environments such as VR, creating a hybrid space halfway between the real world and immersion-in-abstraction. This hybrid immersive set-up, combining both stereoscopic and interactive visual texts, allows for a sense of creative inspiration and inquiry into the dreaming mind, and participants can actively choose to explore the various aspect of their perception by oscillating between two very

different states: an immersive dream sensation and a sense of being anchored in the real world.

The aim of such an experience is not to purposely escape to a mediated world, as is commonly the case with VR experiences, but to engage in a hybrid environment where participants can be immersed in a lucid dream-like experience. Research suggests that people who experience more vivid dreams and exert more control over their dreams are more creative (Yu 2020: 92). From this vantage point, we can assert that it is beneficial to experiment further into the uses of different types of virtual media and visual technologies and their impact on the conjuring of mediated hallucinations or 'dream-like' states. Hybrid forms of immersive, interactive experiences such as *Vœrtex* can inspire us to further investigate the perception of dreams, hallucinations and other types of mental states that connect to a heightened level of lucidity.

As such, the research presented in this article points towards new perspectives and novel questions in the fields of VR and expanded media, opening up potential future research and artistic projects. It is suggested that future research can benefit from providing some clearly defined hypotheses and controlled experiments for perceptual studies. Experiments could be conducted by carefully separating the many variables for tests, which include stereoscopic effects, binocular rivalry, disparity, positive and negative parallax, sense of depth, different types of abstract graphics, etc. By isolating them and making them more pronounced, they would be easier to detect in experiments. One of the limitations of this study lies in the use of an artistic piece, which can be too complex, rich and fast-moving, with many things happening at the same time or in rapid succession. This makes it hard to elicit precise audience responses to specific parameters.

In future studies, we might also test the stereo acuity of participants before the experiments. Nevertheless, a substantial amount of useful preliminary feedback from the audience has been collected and addressed in this study. Artistically, we hope that we have shown through this study of *Vœrtex* that the artist has successfully made use of advanced technology to combine abstract animation, stereoscopy and immersion.

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NOTES

1. Max Hattler's article 'Rupturing visions: Towards an expanded stereoscopy' (2019) constitutes a rare discussion of abstract and experimental moving image works that explore the potentials and possibilities of expanded, artistic approaches to stereoscopic vision or 'expanded stereoscopy'.

2. For example, CAVEs were used for training subjects in landing F-16 aircraft.

3. The vvvv is a visual/textual live-programming environment for easy prototyping and development. This multipurpose toolkit facilitates the handling of large media environments with physical interfaces, real-time motion graphics, audio and video.

4. Adobe After Effects is a compositing, animation and motion graphics application developed by Adobe Systems that is used in the production and post-production of various media, including films, video games and television.

5. Developed by Berlin-based Ableton, Ableton Live is a digital audio workstation for music composing, recording, arranging, mixing, mastering and live performance.

6. Developed by Unity Technologies, Unity is a game engine which supports different platforms, including desktop, mobile, console and VR.

7. Convergence means that 'when a near object is fixated, the lines of sight converge toward that object and the pupils appear nearer to the nasal sides of the eye' (Braunstein 1976: 13). Binocular disparity refers to stereoscopic vision enabled by the lateral positioning of a human's two eyes, since the images projected onto the retinas of the two eyes are different. As a result, 'a realistic impression of depth can be obtained by presenting separate pictures to the two eyes, drawn from two viewpoints corresponding to the interocular separation' (Braunstein 1976: 15).

8. The technical definition of VR is that it is

> a scientific and technical domain that uses computer science (1) and behavioural interfaces (2) to simulate in a virtual world (3) the behaviour of 3D entities, which interact in real time (4) with each other and with one or more users in pseudo-natural immersion (5) via sensorimotor channels.
>
> (Fuchs et al. 2011a: 8)

9. A small number of participants replied that they perceived what could be described as hallucinatory sensation which allowed them to engage in 'another space to escape from reality'.

10. A similar state of simultaneously paying attention to both what is seen in the representation and the actual features of the medium itself through which a representation is depicted has been raised by art scholar Richard Wollheim, whose seeing-in theory of

pictorial representation underlines the ‘twofoldness’ of mediated experience (Wollheim 1968: 212).

11. ‘If we follow Merleau-Ponty, the simplest perception is already a form of expression, perceiving is already a way of acting since it always entails the movement of the body, and, in other words, since our perception expresses the world, recreating it’ (Dalmasso 2019: 116).

12. Following animation scholar Pamela Turner, abstraction ‘does not necessarily exclude representational imagery as it implies that its images are pulled or abstracted from recognizable forms, often leaving little to no reference to the original subject’ (Turner 2003). Some scholars also expressed that abstract visual art can be ‘parasitic on the representational’ (Walton 1988: 352) as artworks sometimes consist partly in their departure from a representational norm, or through the process of segregating and extracting certain information from important aspects or signature qualities of objects and landscapes (Gremmler 2014: 24).

13. The terms ‘abstract film’ and ‘visual music’ can be used interchangeably (Evans 2005: 11), since the term visual music has been used in an effort to define the genre of abstract film, and visual music traditions generally focus on non-representational elements (Turner 2003).

14. Dream sensations such as flying or floating are also common indicators of lucid dreaming (Van Eeden 1913).