Virtual Reality as a Medium for Designing and Understanding Transformative Experiences: The Case of the Overview Effect

by

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Abstract

A unique experience of seeing the Earth from outer space produces a profound emotional reaction in most astronauts leading to a cognitive shift increasing their feeling of connectedness and a sense of responsibility for our planet. This experience, called "Overview Effect", is a remarkable example of a transformative experience. However, such phenomenon is not only inaccessible to the majority of the population, it's also inaccessible to most researchers interested in studying it. Can Virtual Reality (VR) serve as a novel medium for creating environments that invite transformative experiences? I propose a transformative framework suggesting how VR can facilitate progression though a transformative experience; analyze interviews of astronauts and derive specific design and evaluation guidelines for a virtual experience of the Overview Effect; describe the development and report on the initial study with a VR experience *"AWE"*, inspired by the Overview Effect. The results suggest that VR is a viable transformative medium.

Keywords: transformative experiences; transcendent experiences; overview effect; virtual reality; positive technology

Dedication

This thesis work is dedicated to my loving and inspiring family: to my mother, Olga, for her tremendous support and ensuring that I have the best environment to excel; to my father, Rouslan, for his inspiration for scientific curiosity and courage to pursue my interests; to my grandfather, Valera, for the high expectations that push me forward; to my grandfather, Alexander, for his love, belief and pride in me; to my grandmother, Natalya, for her wisdom and teaching me to be a grounded person; and to my grandmother, Valentina, for the love, care and treats. Thank you for being my role-models and support on the homefront.

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"There are no passengers on the Spaceship Earth, we are all crew"

– Marshall McLuhan

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Chapter 1

Introduction

The world is facing a lot of challenges ranging from climate change and other environmental concerns (Urry, 2015) to the growing rates of mental health issues (World Health Organization, 2017), such as depression and anxiety. At a core, both of these problems can be improved if people have a stronger feeling of connectedness, which will contribute to their well-being and also increase their sense of care for others and the environment. How can we promote this change? Turns out there is a cluster of experiences, described as 'transformative', that accomplish this exact goal – increase one's feeling of connectedness, restructure their worldview and motivate a positive behavioral change. An especially powerful example of such experiences is the *Overview Effect* – the cognitive shift in perspective happening to astronauts when they see the Earth from outer space and realize how overwhelming beautiful it is, but at the same time how fragile it is, and how all the living species are united together as inhabitants of our *"Spaceship Earth"* and it's our duty to protect it (White, 2014).

Not everyone, however, gets a chance to fly out into space to appreciate the beauty of our planet and experience the profound cognitive shift. Is there a way to find other environments that can afford such profound transformations to happen? The immersive technology may come for the rescue. The ability of immersive technologies, such as Virtual Reality (VR), to give a sense of presence or 'being there' (Sanchez-Vives and Slater, 2005) and its ability to trigger affective experiences (Riva et al., 2007) may provide us with an opportunity to design environments that could invite transformative experiences to happen. However, within this emerging media the questions remain – how exactly can we go about designing such experiences? What are the important components of it? Do we try our best to replicate the real world scenario or do we learn from it, but design experiences taking the advantage of the unique affordances of the technology? And once the virtual experience is created, how would we know if it was successful at inviting a transformative experience to happen?

There is a lack of research about transformative experiences, which is particularly true for the Overview Effect. Such experiences are very complex, rare and hard to induce, which

makes them difficult to study. As a result, we have little understanding of what are the essential precursors and what is the progression of a transformative experience, that we could have used to guide the design of the immersive installation that could facilitate the progression of such experience. We know a little more about the desired outcomes of transformative experiences than about its precursors, but most of our understanding is based on interviews conducted with a large delay after the experience, which provides little guidance for what would be possible evaluation methods we can use and how they align with our understanding of a transformative experience being a process unfolding through time, and, thus, it should be possible to track this progression at different stages of the transformation process. Andrea Gaggiolli (2016) proposed a transformative experience design framework that describes how a cognitive shift in one's worldview happens through a process of accommodation of the new experience. In **the second chapter, "Transformative Framework",** of this cumulative thesis, I am expanding on that model to build a transformative experience framework, that outlines the stages of the transformation starting from a novel perceptual experience and leading to changes in behavior, which is the ultimate desired outcome of designing for transformative experiences. This framework allows us to view the transformative experiences as a continuity of stages and transitions between them that can allow us to see how VR technology can assist with initiating and transitioning between the stages. It also informs us how different evaluation methods can be integrated in a study of transformative experiences induced through VR in order to assess whether the transformative experience got initiated and how much further it was able to develop, which would suggest which stages or transitions were or weren't successfully facilitated. This framework is used as a generic high level structure when further discussing the creation and evaluation of the VR experience in this thesis.

The Overview Effect is a powerful example of a transformative experience with profound and long-lasting effects (White, 2014; Suedfeld et al., 2012; Ihle et al., 2006; Yaden et al., 2016), but at the same time it is one of the most inaccessible experiences – this creates a perfect case for it to be the inspiration for a virtual transformative experience. Given very limited amount of research on the phenomenon of the Overview Effect, how can we go about designing a virtual experience aiming to induce it and how would we know if it did? **The third chapter, "Space – the Virtual Frontier",** analyses the existing research on and records of the Overview effect and proposes the design and evaluation guidelines for a virtual experience designed for it. Some of these guidelines are implemented in the design and evaluation of the *"AWE"* experience discussed in the following chapters.

A key emotional component of a transformative experience, such as Overview Effect is the emotion of *awe*. It is the direct outcome of the first stage of a novel Perceptual experience in the Transformative Framework, that will then trigger the accommodation process leading into the second stage of Cognitive Shift (Chirico and Yaden, 2018; Keltner and Haidt, 2003). Given the principal role of awe in the first stage of a transformative

process of the Overview Effect and it being the first measurable outcome, we focused the design of the virtual experience on eliciting this specific emotion. **The fourth chapter, "Creating AWE",** describes the design of the virtual mixed reality installation *"AWE"* – Awe-inspiring Wellness Environment. It specifically highlights how, when the goal of an installation is to elicit a distinct emotional response, it is useful to employ a research based design process to guide the development of the installation.

As part of a research-based design process we were evaluating the prototypes of *"AWE"* as an integral part of the development process. In **the fifth chapter, "Understanding AWE",** I am reporting on results of a study based on the second prototype of *"AWE"* where we purposefully invited expert participants who are knowledgeable in the field of using technology for positive impact on society. This study analyses the experience of participants (immersants) going through *"AWE"* to understand it as its own phenomenon of an experience of an affective virtual installation. The study also evaluates results based on the guidelines proposed in the third chapter of this thesis and Gallagher's studies (2015) and assesses whether the experience that participants had in *"AWE"* intersects with components of astronaut's experience of the Overview Effect. The results are indicating that there is an intersection of these two phenomena, but the *virtual overview effect* should be explored as its own intriguing category of transformative experiences.

The final chapter provides conclusions and outlook for future development of this research area.

In this cumulative thesis the Chapters 2 – Chapter 5 correspond to the following publications:

Stepanova, E. R., Quesnel, D., & Riecke, B. E. (2018, May). Transformative Experiences become more accessible through Virtual Reality. In *Proceedings of IEEE Virtual Reality*, Reutlingen, Germany: IEEE (in print, 2 pages)

Stepanova, E. R., Quesnel, D. & Riecke, B. E. (2018). Space – a virtual frontier: How to design and evaluate a virtual experience of the Overview Effect promoting the feeling of connectedness. *Frontiers in Digital Humanities.* (under review)

Quesnel, D., Stepanova, E. R., Aguilar, I., Pennefather, P. & Riecke, B. E. (2018, August). Creating AWE: Artistic and scientific practices in research-based design for exploring a profound immersive installation. In *Proceedings of 2018 Game, Entertainment and Media Conference(GEM).* Galway, Ireland: IEEE. (in print, 8 pages)

Stepanova, E. R., Quesnel, D., & Riecke, B. E. (2018). Understanding AWE: Can a virtual journey, inspired by the Overview Effect, lead to an increased sense of interconnectedness? *Frontiers in Digital Humanities.* (submitted).

Chapter 2

Transformative Framework

Transformative Experiences become more accessible through Virtual Reality

2.1 Abstract

Virtual Reality (VR) has immersive powers that can teleport an immersant into a virtual world and provide them with an experience of being somewhere that they may not have been able to go to. These powers of VR are most often used for games and entertainment, creating a space for escapism and isolation that may have negative psychological and societal outcomes. In this paper, we argue for an opposing application of VR technology – for promoting wellness and feeling of connectedness with people and the world around us. Such feelings can be elicited as a result of a profound awe-inspiring experience, that expands one's mental model and consequently leads to a positive behavioral change. Such experiences are described as transformative, or in strong cases 'pivotal'. Unfortunately, these experiences are rare, only accessible by some people, and nearly unavailable for researchers interested in studying this phenomenon. The immersive powers of VR present a unique opportunity to reproduce such experiences in the lab or at home, thus making them accessible both to the public and to the researchers. Having real-time access to an experience of the immersant will allow the researchers to study the progression of the tranformative experiences and understand its effects and precursors. In this paper, we are proposing a framework through which transformative experiences can be studied in VR. Understanding this phenomenon will inform how VR experiences should be designed in order to create a positive impact on our society.

2.2 Introduction

A few fortunate individuals have an opportunity to have a profound experience in their lives that evolve them as a changed person. Such experiences are often described as transformative or, in strong cases, 'pivotal' or, when interpreted through spirituality, transcendent.

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While these experiences have a positive psychological effect, they tend to be very rare, and difficult to study (Levin and Steele, 2005). These experiences most often occur when an individual observes the vast beauty of nature, for example when one climbs a mountain (Tsaur et al., 2013), reaches Antarctica (Powell et al., 2012) or looks at Earth from space (White, 1998). As such, for most cases these experience are only accessible to the privileged group of people, who have the physical and financial means to travel to the places where a transformative experience can occur. We posit that Virtual Reality (VR) technology can increase the accessibility of such experiences for both researchers interested in understanding them and the larger population interested in experiencing them (Riva et al., 2016b; Gaggioli, 2016; Riva et al., 2016a)

2.3   Current challenges

Currently transformative experiences are very difficult to study because they are rare, private and complex. As such, for the researchers interested in better understanding and researching these experiences, it is fairly difficult to find individuals who have gone through a transformative experience. Transformative experiences are very private, thus, even if a researcher happens to be next to the person who is having a transformative experience at that moment, any intrusion from the researcher will prevent the experience from happening. Therefore the only information available for the researchers is retrospective, with a long delay between the experience and the interview or survey, which makes this measure prone to recall and interpretation errors (Henry et al., 1994).

An individual experience of a person having a transformative experience will be different from an experience of another individual (Tsaur et al., 2013). Not only will the individual variables have an effect on each personal experience, but the environment in which these experiences occur also differ, thus making it even more difficult to make generalizations from the collected interviews.

2.4   The Framework

We are proposing a framework (see Figure 2.1) that discusses transformative experiences as transitions between three stages: perceptual experience, cognitive shift and behavioral change. We are proposing how VR can be used in order to create a controlled environment to apply this framework to study transformative experiences.

2.4.1   Perceptual Experience (Stage 1)

We posit that a transformative experience starts from a novel perceptual experience that is able to elicit an emotional response. In many cases, this experience has the property of perceptual vastness which elicits emotions such as awe (Klatzky et al., 2017; Keltner and
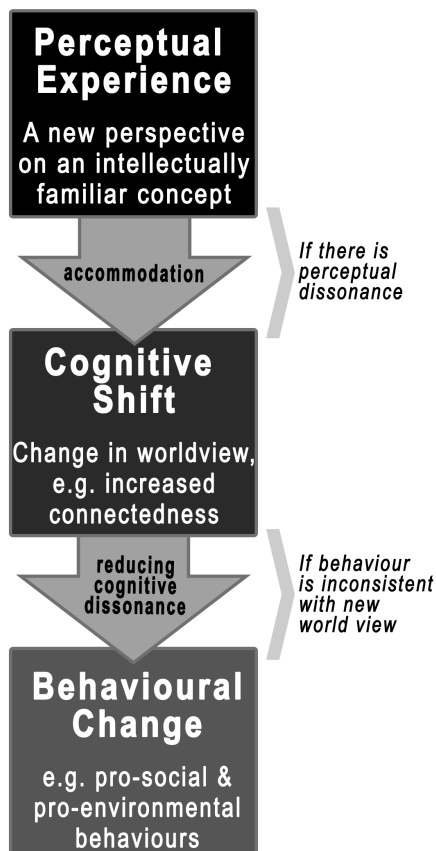
Figure 2.1: Tranformative Framework

Haidt, 2003). VR technology can be used to create vast stimuli, and in combination with an affordance of inducing the sense of "presence" it has the potential to elicit awe-inspiring experiences (Chirico et al., 2016). As the environment is created in the VR it will remain more or less constant between each participant of the study, thus having this environmental variable controlled.

This stage can be studied in detail through physiological measures. Biosensors such as heart rate variability, galvanic response, and goosebumps (Quesnel and Riecke, 2017; Benedek and Kaernbach, 2011; Grewe et al., 2009b) can help identify specific moments in the experience that resulted in an emotional response in the participant. Another evaluation method that should be paired with physiological measures is cued-recall debrief (Bentley et al., 2005), where the participant re-immerses inside their experience while watching a recording of it. This measure is less prone to memory errors than interviews, and will allow the researcher to disambiguate events observed in the recordings of the physiological measures. Correlating all of these measures with the recording of participant's view will give the researchers access to the specific moment of change for the participant, and the relation to the components of the virtual system. This would provide the valuable information about

the effectiveness of the specific elements of the design of the virtual environment in ability to trigger affective response.

2.4.2 Transformative Design Framework (Transition 1)

Andrea Gaggioli (2016) proposed a framework that explains how the transition from the perceptual experience to the cognitive shift happens. When presented with a powerful and novel perceptual experience, an individual has three options of dealing with it: assimilation, accommodation or rejection. If an individual is able to fit the experience into their current worldview, then the experience will get assimilated and no further change will occur. However, if the experience does not fit with the worldview, thus there is a perceptual dissonance, then the worldview ought to change to accommodate for the new perspective, which would lead to a cognitive shift. However, if the individual is not able to accommodate the new perspective it will get rejected, by finding an alternative explanation for the experience, e.g. an illusion or a hallucination. While in the real world, this third option of rejection is less likely to occur; in the case of a VR experience, it is easy to disregard it as not real. Thus it is important for the researchers to pay attention to how they prepare the participant to the experience by carefully building trust in the system.

2.4.3 Cognitive shift (Stage 2)

After a successful accommodation, an individual will experience a cognitive shift in their worldview, or an expansion of their mental model. This stage is the most challenging to assess, as it requires the use of implicit measures that can tap into the structure of the cognitive system of the participant. Such measures can use physiological measures such as eye-tracking, or tests that rely on reaction time or disambiguation (Wittenbrink and Schwarz, 2007).

An example of such implicit measure is an Implicit Association Test (IAT) (Greenwald et al., 1998), that can, e.g., be used for assessing one's connectedness to nature (Schultz et al., 2004; Bruni and Schultz, 2010), which is one of the observed outcomes of transformative experiences (Williams and Harvey, 2001). This is a computerized test that uses reaction time to assess how closely one associates "self" with "nature". A disambiguation test can use ambiguous images or stories to infer participant's attitudes from his interpretation of the stimuli. Tests that rely on reaction time have more noise than disambiguation tests, but they provide a continuous measure and they are more resilient to social desirability bias.

2.4.4 Theory of Cognitive Dissonance (Transition 2)

Similarly to the transformative design framework, cognitive dissonance theory (Festinger, 1962) explains the transition from the cognitive to behavioral change through emergence of a disequilibrium and the desire of the cognitive system to return to equilibrium. Thus if

the new worldview is inconsistent with current behavior of the participant, then to resolve the conflict either the worldview or the behavior will need to change. Since the worldview has just been adjusted in order to accommodate for the perceptual experience, at this stage adjusting the worldview will create a new conflict, so the only way to achieve the equilibrium would be to modify one's behavior to reflect new values of the expanded mental model.

2.4.5   Behavioral Change (Stage 3)

The ultimate goal of understanding how to design the transformative experiences is to create a caring society where an individual will find it unnatural to behave in a way that is destructive or ignorant. This stage can be evaluated through behavioral measures such as observing participants' pro-social (Rosenberg et al., 2013) or pro-environmental (Ahn et al., 2014) behaviors. These observations are performed with deception by staging a situation to which a participant has to react, e.g. experimenter can drop pens (Rosenberg et al., 2013) or spill water (Ahn et al., 2014), and then participants behavior is observed. This measure can also use reaction times.

However, it is important to consider the timeline at which this change occurs. While taking this measure right after the VR experience is convenient, it will be prompt to two possible issues: 1) it may not capture the change that requires longer processing time before the cognitive system achieves equilibrium, thus producing a false negative result in the measure; or on the other hand, 2) it may also produce a false positive result, by failing to assess longitudinal effects of the experience.

2.5   A Case of The Overview Effect

For the specific example of how this framework can be applied, we want to discuss the Overview Effect. The Overview Effect is the profound experience that astronauts have when they see the Earth from space, and realize how beautiful and fragile the planet is, and how we all as living species need to unite together to protect our home planet (White, 1998). This is a strong, profound experience with long-lasting positive psychological effects (Suedfeld et al., 2012; Ihle et al., 2006). A lot of astronauts after returning to Earth start engaging in pro-social and pro-environmental activities (Garan, 2015). However, as space flight is inaccessible to the majority of the world population, this presents a perfect case for VR technology to step in and deliver an experience to the general public that could induce the Overview effect (or an extent of it) without shooting rockets into space. In order to evaluate whether the VR experience was able to achieve an extent of the Overview Effect, the researchers can look for the emotion of awe and wonder felt (Gallagher et al., 2015; Quesnel and Riecke, 2017), the cognitive shift leading to increased connectedness with nature (Schultz et al., 2004; Bruni and Schultz, 2010), and observe pro-social (Rosenberg et al., 2013) and pro-environmental (Ahn et al., 2014) behaviors.

We are iteratively working on a prototype of a VR experience inspired by the Overview Effect; the user tests are indicating that the VR experience is effective in eliciting desired emotional responses and has potential for inducing a cognitive shift (Quesnel, 2017). However, the description of our prototype and the results of the tests are out of the scope of this position paper.

2.6 Conclusion

VR can provide a unique opportunity for researchers to study a very complex and personal phenomenon of transformative experiences in a controlled lab environment, making these profound positive experiences accessible for both the researchers and general public willing to improve their well-being. Such transformative VR installations can be made available to the public in culture spaces, such as museums and art galleries, thus not only providing access to these positive experiences to general public, but also giving researchers a potential access to a wide range of participants. In the future, when VR technology becomes even more widespread and the transformative experiences design is well understood, these VR experiences can be made available for the public to use at the comfort of their own home for improvement of their well-being akin to mobile meditation apps. However, the design of the experience and the research of it are interdependent, and thus we will need to design and evaluate the experience and the evaluation methods, proposed for assessing the progression through stages of the transformative experience, through an iterative process, at the end of which we will build the knowledge of how to design VR experiences for well-being and a positive change in society.

Chapter 3

Space – A Virtual Frontier

How to design and evaluate a virtual experience of the Overview Effect promoting the feeling of connectedness

3.1   Abstract

A select group of people have an amazing opportunity to see the Earth from a unique perspective – in outer space. The effect this experience has on an individual is described as extraordinary and profound, consisting of a cognitive shift in worldview that leads to the understanding of the fragility and vulnerability of the planet, and an increased feeling of connectedness. This experience, termed the "Overview Effect", has been reported by many astronauts and space travelers. Its key outcome – an enhanced feeling of interconnectedness – contributes to both one's well-being and the sense of responsibility for the Earth. If this profoundly positive experience can be accessible to more people than just space travelers, a healthier and more caring society may be created, where individuals deeply feel the interconnection of all living beings and responsibility for our collective future. Given virtual reality (VR) technology's potential to induce experiences affecting an immersant in a similar way as a real experience, we see an opportunity to leverage this technology to attempt to elicit the Overview Effect as a virtual experience. Through a virtual installation, the experience could be made accessible to people around the world, and for researchers to study this otherwise rare phenomenon. This article builds the case for VR as a tool for inducing the Overview Effect, and proposes guidelines for: 1) the design of the experience; 2) evaluation methods for assessing if, or to what degree, the experience was achieved. We invite researchers and VR creators to utilize and expand on the guidelines proposed in this paper to design transformative VR experiences that induce positive change, and promote a feeling of connectedness and care for each other, and our Spaceship Earth.

3.2   Introduction

Our world is facing a lot of challenges in the domains of the environment, sustainability, and social stability. While some challenges may not yet have an obvious solution, there are some well-known small steps each individual could take to help protect the environment and minimize social tensions and social segregation. Despite this intellectual awareness, a lot of people still neglect to take required action. If a way exists for a larger portion of our population to incite this transition from intellectual surface knowledge to deep internal understanding, this could be a key to solving some of the big challenges our world is facing. Even though there are a lot of efforts being put towards addressing these issues, the rate of progress could be improved if we all unite together to tackle them.

On a more individual level, another concerning issue is the rate of depression that increased by 18% from 2005 to 2015 according to World Health Organization (2017), with mental disorders being a leading cause of disability (Whiteford et al., 2013). People often find themselves feeling isolated and lacking profound social connections, which can contribute to increased depression and detachment. Despite rapid developments of technology designed to facilitate communication and connection between people, such technology is often (although not always) associated with the opposite effect of increased loneliness and depression (Kraut et al., 1998; Kross et al., 2013).

Solving the social disconnect and isolation problem may be the first step towards a healthier, happier and more caring society. So how can we promote the feeling of connectedness? There is a rare but powerful experience that appears to have this exact effect: it's the experience that astronauts have when they see the Earth from outer space. In his book "The Overview Effect: Space exploration and human", Frank White (1998) analyzed reports of astronauts about this experience, and introduced a term for it – the "Overview Effect" (OE). Micheal Collins, a space pilot, described the importance of the OE:

> *I think the view from 100,000 miles could be invaluable in getting people together to work out joint solutions, by causing them to realize that the planet we share unites us in a way far more basic and far more important than differences in skin color or religion or economic system. The pity of it is that so far the view from 100,000 miles has been the exclusive property of a handful of test pilots, rather than the world leaders who need this new perspective, or the poets who might communicate it to them* (White 2014, pp.109)

The OE has been shown to have lasting positive effects both on individuals (Ritsher et al., 2005; Suedfeld et al., 2012) and society, as evident from a lot of astronauts joining humanitarian and pro-environmental movements after coming back from space (Ihle et al., 2006; Garan, 2015). Nezami (2017) has also explored the OE's potential for psychological therapy and well-being. The findings show that the OE is a profoundly positive experience that can improve an individual's wellness, and promote awareness, pro-social and pro-environmental

attitudes in society. If more people could have a similar profound experience to what astronauts are fortunate to experience, we may create a healthier and more connected society where taking care of each other and the planet would seem obvious and natural. Yet, it is not feasible to send large numbers of people into space with the sole aim of having a profound emotional experience, especially given the high cost, risk, environmental footprint, and physical demands of spaceflight. However, if we better understand what are the key triggers of the OE, we might ultimately be able to simulate this experience on Earth.

This presents a perfect opportunity for Virtual Reality (VR) technology to provide the researchers and designers with a means to study this rare, profound phenomenon, and develop virtual experiences for positive change. The immersive powers of VR allow the immersant to experience being in distant places and be affected by that experience without actually going there (Sanchez-Vives and Slater, 2005). This technological breakthrough is providing us with an opportunity to make the OE more accessible to researchers and the general public.

In order to build the case for VR being a tool capable of eliciting the OE, this paper first summarizes the relevant research suggesting that VR technology is capable of inducing an experience that could lead to a positive change. Since OE is a rare and complex phenomenon, there is no complete understanding of its components, triggers and progression. The primary focus of this paper is to analyze existing research and reports of the OE, and extract specific design guidelines from the research for the creation of a VR experience that could elicit a transformative experience similar to the OE. Secondly, we are suggesting evaluation methods on whether/to what extent the VR experience was able to induce OE, and methods for studying this transformative phenomenon elicited in VR. To achieve these two goals, we are analyzing the astronaut reports described and summarized in Frank White's (2014) and Gallagher's (2015) books on the OE, as well as the scientific research investigating this phenomenon. We also draw from theories about transformative experience design (Gaggioli, 2016; Stepanova et al., 2018b; Kitson et al., 2018b). We apply some of the proposed design guidelines in iteratively designing a prototype of an immersive experience inspired by the OE (Quesnel et al., 2018b), which we evaluated in a study using some of the methods proposed in this paper Stepanova et al. (2018c); however, comprehensive discussion of this prototype is outside the scope of this paper can be found in other publications.

3.3   Virtual Reality for positive change

In recent years, VR technology is rapidly becoming more capable, affordable, and accessible to people, which has prompted the scientific community to explore its potential to be used for research, and for improving human lives.

3.3.1 The mechanism of how VR can influence individuals

First, it's important to discuss the theoretical assumptions that lead us to believe that VR technology can have a strong effect on an individual's cognition and behavior. When analyzing the effects of VR, we need to be aware of the assumptions of the psychological theories that this field is grounding itself in.

Our worldview is based on our experiences of interacting with the world. Through a sensory systems, we observe events in the world, and build a cognitive model that can sufficiently describe our experiences. Later on, we perceive, interpret new information, and act in accordance with our mental model. However, the sensory information we are receiving from the world is often incomplete and in certain cases could be conflicting. To deal with this, our cognitive system relies on multi-sensory integration to register an event. In case of a conflict between multiple sensory inputs, we tend to be biased towards the senses that are stronger, or have higher acuity in humans (Welch and Warren, 1980). For instance, a visual stimulus will usually dominate auditory stimuli as famously observed in the McGurck effect (McGurk and MacDonald, 1976) and ventriloquist illusion (Bonath et al., 2007). Moreover, this effect is prominent even with large conflicts between stimuli that can't be merged into a single event perception: with repeated exposure to conflicting stimuli, our cognitive system adjusts and forms a biased perception. For example, a repeated conflict between visual feedback for a pointing task and spatial memory will bias our spatial perception for all future stimuli by the length of the discrepancy between the received feedback and the memory of the position of the target (Lipinski et al., 2010). Anecdotally, everyone can observe this phenomenon of learning through sensory integration when they step on a non-moving escalator and feel unbalanced and disoriented.

In the context of VR, this effect of multi-sensory integration has been studied in relation to the body ownership illusion (the illusion of experiencing an artificial or virtual limb as a part of one's own body) (Maselli et al., 2016), suggesting that the visual input received through a VR head-mounted display indeed integrates with other sensory inputs in a similar manner to a visual input received from the real world. Another example of multi-sensory integration in VR is vection (self-motion illusion) (Riecke, 2010) – the compelling sensation of self-motion induced by the visual or auditory stimulus akin to the sensation experienced when seeing a train starting to move from a window of one's stationary train. This mechanism of our cognitive system makes immersive VR technology extremely potent to create experiences that in effect, might be indistinguishable from real world experiences. We see this in the example of vection, where the illusion of self-motion can no longer be distinguished from actual self-motion (Brandt et al., 1973). A common critique of the potential of VR technology at present is that it doesn't always have comprehensive sensory information, such as haptic, or olfactory capabilities. However, the combination of the multi-sensory integration and a high reliance on visual channel (for human species) provides VR

with enough power to create experiences that can affect the structure of our mental model akin to real world events. Even when the VR system doesn't produce a perfectly complete experience for all of our sensory channels (e.g. lack of haptic or vestibular input), our mind will fill in these gaps based on the available input (e.g. visual and auditory).

Embodied cognition is another theory that explains how VR experiences can affect our cognition (Bailey et al., 2016). According to this theory, the mind is not "locked" within one's brain, but rather is heavily based on our body (Wilson, 2002). Consequently, an immersive VR experience that engages one's body in the experience will affect cognition on a stronger and deeper level than a solely visual experience in less immersive media. VR tends to elicit more realistic behaviours and reactions due to a feeling of embodiment and use of multisensory input (Slater, 2011; Wilson and Soranzo, 2015).

3.3.2 Evidence of transformative powers of VR

In recent decades, as VR technology has been rapidly developing, many researches have been investigating its psychological and societal application, and its ability to induce positive change in an immersant. An extensive review of VR applications for mental health provided by Riva and colleagues (2016a) and Freeman and colleagues (2017) show the growing potential of the technology. Jeremy Bailenson's lab at Stanford University studies the social application of virtual experiences and how it can induce positive behavioral change. For instance, Rosenberg et al. (2013) study observed increased pro-social behavior in participants who flew like a superman around a virtual city. In a different experiment by Ahn et al. (2014), participants performed more pro-environmental behavior after virtually cutting down a tree. The effects of virtually embodying a body other than one's own have been extensively explored: taller avatars would argue more aggressively (Yee et al., 2009), slimmer avatars have smaller body image (Serino et al., 2016); the cognitive effects are shown in increased connection to nature after embodying a cow (Ahn et al., 2016); stereotyping and biases get reduced when embodying an avatar of outer-group (Maister et al., 2015), stereotyping against elderly is reduced when embodying an older avatar (Yee and Bailenson, 2006), likewise embodying an other-race avatar reduces racial biases (Peck et al., 2013; Hasler et al., 2017; Banakou et al., 2016), while having a virtual out-of-body experience reduces the fear of death (Bourdin et al., 2017). This evidence from academic research on VR shows that even a few minutes of VR experience can effect our behavior and worldview, at least for a short-term (immediately after the VR experience, when the measures are taken). Thus, we have a reason to believe that a well-designed virtual experience of a spaceflight might be able to induce an OE and lead to the cognitive shift and behavioral change associated with the OE. Additionally, it would be important to assess the long-term effects of such experiences.

3.4 A summary of the Overview Effect

The term "Overview Effect" (OE) was first coined by Frank White in his book (White, 1998), where he describes this profound experience reported by astronauts who saw the Earth from outer space. White describes it as a cognitive shift, or shift in awareness that resulted in a new worldview leading to an enhanced sense of responsibility for Earth. This effect is reported by most astronauts and space travelers, but can be described differently by each individual. However, these descriptions have common characteristics that suggest that it is a singular phenomenon. The descriptions start with the admiration of the overwhelming beauty of the Earth and realization of its fragility leading to the feeling and understanding of interconnectedness of all life, and the concern and responsibility for our home planet and its inhabitants.

3.4.1 Possible explanations of the OE

Even though OE is a rare phenomenon making it difficult to build a comprehensive understanding of its causes and progression, there are a number of proposed theories that could explain the mechanism of OE, which we will discuss below.

3.4.1.1 Dissonance

In his foreword to the third addition of Frank White's book (White, 2014, pp. xiii), astronaut Ron Garan describes his own experience of OE: "*At its core is the contradiction between the beauty of our planet and the unfortunate realities of life on the surface for many of its inhabitant*". Ron Garan, author of the book "The Orbital Perspective" (2015) identifies the key mechanism through which OE develops to be the emergence of a dissonance between the observed and perceived reality. Our cognitive system strives to be in an equilibrium, thus it adjusts when a dissonance is introduced and the system has to adjust to reduce it. This mechanism, for example, is illustrated in the theory of cognitive dissonance (Festinger, 1962), which explains the alignment of one's mental model and behavior and consequently can be used to modify the behavior or the mental model. The similar process of accommodation explains how the mental model is adjusting to incorporate a new profound perceptual experience (Gaggioli, 2016). Thus, encountering this new perspective on Earth from space pushes space travelers to reassess their existing mental model when attempting to assimilate their experience. If this new experience introduces a dissonance into the cognitive model, the model will have to be adjusted to reduce the dissonance and accommodate the new experience, thus producing a cognitive shift, when "the physical and mental realities are brought into alignment" (White, 2014, pp.17). Edgar Mitchell described it as an "aha" experience: "*To me the difference between getting and not getting an "aha" experience of it is whether it shifts your structure a bit. Do you get a sense of freedom, of expansiveness, because you've just experienced something that is different from your previ-*

ous experiences and beliefs" (White, 2014, pp. 25). As such, the VR experience needs to be designed with a goal to induce this dissonance and facilitate accommodation, as discussed in Stepanova et al. (2018b) and Gaggioli (2016).

3.4.1.2 Transcendence and Awe

Yaden and colleagues (2016) analyzed the interviews of astronauts and identified the emotion of *awe* and *transcendent experiences* as key components of the OE. Research in the domains of transcendent experiences and awe-inspiring experiences describe the effects and traits as similar to common characteristics of the OE. Interestingly, research demonstrates that the traits and effects of both transcendent experiences and awe-inspiring experiences is strikingly similar to that of the OE. However, both transcendent and awe-inspiring experiences are not perfectly defined as a singular type of phenomenon, and thus only some research from these domains will be relevant to the OE. What complicates this is the lack of consistency in how the terms "awe" and "transcendent" experiences are used: both terms could be used to describe different phenomena, and other terms can be used to describe the same or a similar phenomenon, e.g. a "peak experience". A detailed analyses of the terminology, properties, and indicators of these profound experiences and the overlap between them would be useful, but is outside of the scope of this paper. For a recent overview of awe and self-transcendent emotions see Chirico and Yaden (2018). Here, we provide a short summary of a few relevant aspects of the research on transcendent and awe-inspiring experiences that can be used for better understanding and designing for the OE.

Transcendent experiences are describing a profound, usually spiritual experience leading to an expanded awareness and dissolution of one's ego and the feeling of global interconnectedness (Levin and Steele, 2005). Although sometimes transcendent experiences are described without a spiritual interpretation, most of the descriptions of transcendent experiences still consider it a form of a spiritual experience. Even though the OE is only described as a spiritual experience by some of the astronauts, the description of the effects of the OE and transcendent experiences are fairly similar, so we can use our knowledge of transcendent experience to help understand the OE. Transcendent experiences are described in multiple different contexts, such as: yoga practice and meditation (Berkovich-Ohana and Glicksohn, 2017), flow states during sport and music practices (Csikszentmihalyi and Csikszentmihalyi, 1992), interaction with nature (Tsaur et al., 2013; Powell et al., 2012; Williams and Harvey, 2001; McDonald et al., 2009), and near-death experiences (Greyson and Stevenson, 1980; Kohr, 1983). The main characteristic of transcendent experiences is the feeling of oneness with the universe, nature, the divine or God, depending on how it is interpreted by an individual. Other shared characteristics with the OE are an aesthetic pleasure of the experience, restructure of consciousness to encompass the new experience, transcendence of time and space, and positive changes in attitudes and behavior. For a historic overview of investigations of transcendent experiences, see Levin and Steele (2005).

Awe-inspiring experiences could account for some of the effects of the OE. Awe is a psychological construct that is considered part of a "self-transcendent" index of emotions, and is characterized by the perception of something vast, followed by a need to accommodate the experience (Keltner and Haidt, 2003). "Vastness" is a perceptual sense, in that many people have experienced it in nature with a breathtaking vista, or in the case of astronauts, the vastness of space containing our planet. Music, art, architecture, media forms, and social situations all can inspire awe (Grewe et al., 2011; Keltner and Haidt, 2003; Maruskin et al., 2012; Shiota et al., 2007), with awe even experienced by comprehending technology (Bai et al., 2017). Awe is different from many positive emotions like joy, in that awe can significantly shift attention away from the self, whereas joy results in self-focused attention (Shiota et al., 2007; Keltner and Haidt, 2003).

Yaden et al. (2016) explain that while it may be tempting to describe awe as a perceptual or aesthetic emotional experience in the case of viewing the Earth from space, there are a few unique features that factor into how this awe-inspiring experience promotes a feeling of connectedness. Among those is a sense of "totality": "*. . . the tendency is, quite literally, to think in global terms, and that the ability to behold all at once the entire domain in which these human themes reside contributes to the overwhelming sense of awe*" (Yaden et al., 2016, pp.4). The authors explain that seeing the Earth from above may disconnect an individual physically from their home but helps form an emotional connection that sees humankind as an entirety, connected to one another. A key characteristic of awe is the "small-self" perception, which is a feeling of one's personal identity receding and reducing in significance when faced with an awe-inspiring experience (Bai et al., 2017; Piff et al., 2015), a feeling akin to humility. This is seen in statements such as "*I feel the presence of something greater than myself*" (Piff et al., 2015, pp.6).

An outcome of this is an individual's need to assimilate into a social collective, which requires them to set aside their own self-interests and assume the needs of the group (Keltner and Haidt, 2003). In this regard, it should not be surprising that awe is often elicited at collective engagements, like concerts, rallies, and spiritual rituals (Shiota et al., 2004). Compared to other emotions, like pride, that are thought to promote a *desire to belong* to a social collective, individuals who experience awe report a *stronger connection to collectives* (Shiota et al., 2007). This feeling of awe may be why seeing a conceptual wholeness of humanity in the form of the Earth is so profound for astronauts. The experience of profound awe during the OE and its tendency to induce a perception of small-self (self-diminishment) is of great interest when exploring how individuals may feel, and demonstrate connectedness as a result of the experience.

3.4.2   Negative psychological effects of a spaceflight

The spaceflight experience and the view of Earth from space is not solely described as a positive experience. The opposite effects of "break-off" – the feeling of separation from Earth

and anxiety in astronauts and high altitude jet pilots (Clark and Graybiel, 1957; Sours, 1965), stress and feelings of confinement and isolation (Morphew, 2001) and detachment (Valentine, 2016) are also reported. However, negative effects are reported less frequently than positive, especially in recent years, and seem to be associated with the physical stressors and dangers of a spaceflight, and thus would be less likely to occur in a VR experience.

3.5 Experience Design Guidelines

In this section we extract some common components of the description of the OE by astronauts and propose guidelines for the design of the VR experience for OE, including the setting, pre-VR, and post-VR components of the experience.

3.5.1 Embodied Experience and Self-relevance

White explains that "*our 'worldview' as a conceptual framework depends quite literally on our view of the world from a physical place in the universe*" (White, 2014, pp. 1). Moreover, it doesn't seem to be enough to hear the descriptions or see the images of the perspective; the actual embodied first person experience seems to be crucial for creating this new worldview or mental model. That is, the mere conceptual understanding is not enough to extend one's mental model, when it is not accompanied or elicited by an individual's embodied sensory experience. A number of astronauts were comparing the experience of seeing Earth with the experience of seeing the Grand Canyon: "*The first time you look out at the Earth and see that, it's a heart-stopper. I don't care how many pictures you've seen of the Grand Canyon, it's not the same as looking over the side and saying, 'My goodness, it is really that deep'*" (White, 2014, pp. 13). Similarly, even though the first pictures taken from space after the first space missions left a strong impressions on general public, and, as Joseph Allen put it, "*you wouldn't have a gotten a penny for EPA* [Environmental Protection Agency] *before those pictures from orbit*" (White, 2014, pp.206), they didn't seem to have been able to induce the OE in the general public. Sandy Magnus, an engineer and astronaut, explains the value of the first person sensory experience:

> *There is a difference between intellectual knowledge and experience-based knowledge. You know it is hot outside when you hear it is 110 degrees, but you don't really know it's hot outside until you walk out the door and you get blasted with a wall of heat hitting you in the face. It is not an intellectual fact anymore; it is experience that you have connected with that piece of data* (White 2014, pp.45).

Even though intellectually astronauts knew, for instance, that there is no dividing boundaries on Earth between countries as we normally see on the globe and maps, seeing boundary elimination for themselves was still surprising, and that experience "provided a crystal clarity", as reported by Edward Gibson (White, 2014, pp.40). It is important to design a VR

experience to provide this believable first-person experience to the immersant, meaning that the experience should feel like a first person experience of traveling through space rather than watching a movie about space on a VR headset. What is probably going to be important for it, is designing for the immersant's sense of self-relevance and agency in the environment, which was shown to play large role in virtual body ownership (Ma and Hommel, 2015) and could sometimes be used to explain the sense of "presence" (Herrera et al., 2006). Thus, the virtual environment should facilitate presence and appear responsive to the actions of the immersant. Adding small effects on multiple sensory channels will make this first-person embodied sensory experience even more likely to occur. For example, when the sun appears virtually, an infrared lamp or heater could provide the experience of warmth coming from the perceived sunlight.

3.5.2   Privacy and Social space

"The experience is relatively private while the astronaut is in space but becomes highly public on return" (White, 2014, pp. 12). The mere fact that astronauts are being interviewed upon arrival makes them process the experience in a new way, as Alan Bean mentioned "You think about it only when people ask you. You were really refining other skills" (White, 2014, p. 15). Thus the interview and discussion might play a role in accommodating the experience. Both stages are likely important for the full processing of the OE, thus the designers of the VR experience will have to face a challenge of creating a space for a very private experience of Earthgazing, while also providing a social space to encourage discussion and processing of the experience after the person comes out of VR.

3.5.3   Visual Style

3.5.3.1   Vastness

As discussed above, awe is identified as a key component of OE. Chirico et al. (2016) proposed to use VR to create awe-inspiring experiences, as it is capable of producing vast stimuli, which are associated with awe (Keltner and Haidt, 2003), and can induce presence and enhance the ecological validity of the experience. The virtual environment should be designed to highlight the vastness of space and possibly other environments that may be included in the virtual journey to build up the sense of awe. However, current VR headsets have some technical limitations including narrow field of view and low resolution.

3.5.3.2   Suspending disbelief through aesthetics

Everyone who has seen the Earth from outer space has been deeply impressed by its beauty. The image seems indescribable, like nothing else experienced on Earth. Marc Garneau called his experience a "dreamlike experience, because space is a very magical place to be" (White, 2014, pp. 218). These descriptions of the marvelous view of the Earth suggest that the VR

experience could be designed in a style of magical realism in order to create a similar dreamlike visual experience. As opposed to hyper-real visual style, magical realism is more likely to facilitate the suspension of disbelief in the immersant, and thus their sense of presence will be less likely to be broken because of imperfections of the technology in representing a realistic environment.

Magical realism is an aesthetic style of art that incorporates a realistic portrayal of our world, with magical or mystical elements fantastical or ambiguous in concept. This style supports positive subjective appraisals of the visual scene while simultaneously experiencing something novel that their imagination can interact with (Faris, 2004). Visuals and art that is too abstract and difficult to understand, or on the flip side, too literal with concrete meaning, tend to elicit less positive emotions (Silvia, 2012). With the example of artist Char Davies' 1995 VR installation "Osmose" 1996, we experience abstract visuals that do not directly illustrate, but rather suggest meaning that is open to interpretation in the mind of the immersant, promoting an imaginative and self-relevant experience, that would be important for eliciting profound emotions.

3.5.3.3 Clarity and contrast

The image that astronauts see is very clear and vibrant, as Nicole Stott described it: "dynamic, crystal-clear view that just glows" (White, 2014, pp. 18). Often astronauts describe the image they have seen as being in high resolution full of detail. For example the first man in space, Yuri Gagarin says: "*The mountain ridges, the great rivers, massive forests, ocean shorelines stood out sharply. I could see both clouds and their faint shadows on the surface of the Earth*" (White, 2014, p. 27). The first time the intense clarity of the image of Earth was described, it was interpreted as a hallucination, but later on, it was suggested that vision may indeed become sharper when leaving the atmosphere. This intense clarity my also be an important contributer to the OE (White, 2014, p. 29). This enhanced clarity might be difficult to achieve with the current resolution of VR headsets. However, the perceived clarity of Earth can be achieved through creating a contrast between the images appearing right before the view of Earth is revealed and the image of the Earth. For example, the VR journey could take the immersant through somewhat blurry undefined clouds or asteroids and then reveal a sharp and bright Earth full of vibrant details, and as such, by contrast, appearing impressively clear.

Similarly, the contrast between the Earth and the surrounding hostile space may also contribute to the perception of Earth as a beautiful and fragile living organism. Schweickart reports:"*The contrast between that bright blue and white Christmas tree ornament and the black sky, that infinite universe, really comes through*" (White, 2014, p. 36). Through defining the contrast between the model of the Earth in VR and its surroundings we can highlight the qualities of our planet admired by astronauts during Earthgazing.

3.5.3.4 Perception of Earth as a living organism

Astronauts highlight how the Earth appears to be a living organism. They describe that it is always changing, you always see "different sides of her face" and "different times of the day" (White, 2014, pp. 1). We can speculate that in some way the OE is a form of empathy developed towards Earth as a living organism that needs care and protection from its inhabitants. Thus, it is important to put a lot of attention to the development of the Earth model in VR, and ensure that it appears alive and dynamic. In particular, astronauts often describe the ever-changing and moving clouds and distinguishable layers of the atmosphere. Multiply layers of atmosphere and lively clouds are probably the simplest way of creating the perception of the Earth being a living organism.

3.5.4 Progression of the experience/storyline

3.5.4.1 Earthgazing Moment

The climax of the VR experience would be the Earthgazing moment – when the Earth will be revealed and the immersant can admire its beauty. Silvia (2012) explains that a violation of expectations and surprise with an aesthetic experience leads to an increase in curiousity and positive emotion with the subject. In the case of the Earthgazing moment in space, many astronauts are not prepared for the incredible vividness and totality of the sight before them (Yaden et al., 2016). This can be attempted in a VR experience with the sudden appearance of the Earth as an incredibly detailed, three-dimensional, and visually immense object. To get the immersant ready and receptive to the introspective moment of admiring the vast beauty of the Earth, the VR experience should take them through a journey and narrative arc building up to that moment.

3.5.4.2 Initial fear

Due to the nature of the spaceflight, the profound OE always follows the frightening experience of being aggressively rocketed into space through the burning of combustive fuel and a volatile atmosphere. As a consequence, each astronaut first has to come to terms with the possibility of death before reaching the point of relief and admiration of the beauty of the Earth. "*When a launch is successful, it is a kind of miracle and blessing that one continues to live, especially in having been transported to a new and extraordinary environment*" (White, 2014, pp. 13). So in some sense the OE could be built on near-death experiences, that are also often found to be transformative (Greyson and Stevenson, 1980). Joseph Allen describes the emotional arc of the journey into space: "*the anxious and interminable waiting, the stunning moment of ignition, the thrill of acceleration and the silent surprise of slow-back space*" (White, 2014, pp.44). By designing for a moment of fear and anxious anticipation in the beginning of the VR experience prior to the Earthgazing moment, we may model the emotional arc of the spaceflight journey, and help the immersant to achieve the

moment of relief and peace. Since most of the potential participants of the VR experience wouldn't be familiar with an experience of being in a rocket, modeling the take-off might not be the best way of inducing a subtle amount of fear. In fact, when Gallagher et al. (2015) designed a space shuttle countdown and rocket takeoff, participants expected an experience akin to an amusement park ride, and their experiences changed to fit that expectation. A more effective method would be to incorporate into the journey an experience of a familiar event that can induce natural fear, such as a sensation of falling, or of a volatile natural phenomenon.

We want to highlight that by no means we are suggesting to design a virtual near-death experience. The design for an initial fear response should be fairly subtle, as it's important to avoid causing any traumatic virtual experiences or leading to immersants losing trust in the system, and may become disengaged to protect themselves from potential negative emotional experiences. The experience of fear should subsequently be followed by an experience of relief or resolution to ease the initial fear.

3.5.4.3 Weightlessness

Weightlessness is a significant part of astronauts' experience, that could possibly account for some part of the OE, but is difficult to achieve on Earth without expensive equipment. However, the designers of a VR experience can *trick* the immersant to experience the sensation of floating, by intelligently creating a transition from one state in the environment to another by changing the soundscape and navigational controls. Let's take a look at how Scott Carprenter described his experiences of silence: "*The first thing that impressed me when I got into orbit was the absolute silence. One reason for this, I suppose, was that the noisy booster had just separated and fallen away... But it was also a result, I think, of the sensation of floating*" (White, 2014, p.19). We can speculate that this connection between the sensation of floating and striking silence works in both directions and can be used in design of the VR experience to create experiences akin to floating.

Even though there are number of waterproof VR headsets being developed (e.g. underwater headset for virtual scuba diving (Nagata et al., 2017) that would allow submersion in water during a virtual experience to achieve some sense of weightlessness, this is probably not a very promising direction, as it will significantly complicate the set-up of the experience and increase overall cost and complexity. Thus we propose to focus on designing for the experience of floating without submersing the immersants into water. Moreover, Gallagher et al. (2015) found in descriptions of astronauts' experiences of awe that seeing the Earth from space was more connected to the sight of the Earth, and seemingly not as much to weightlessness. Without being able to replicate a feeling of weightlessness and test its impact in VR, we are unable to empirically determine the strength of its connection to the OE. At best, we should aim to experiment with the sensation of floating or weightlessness felt in

meditative or dream-states and assess its role as a contributor for the virtual experience of OE, but it shouldn't be the main focus of the design of the experience.

3.5.4.4   Personal connection

Another common theme appearing in the records of Earthgazing, is that at first, before the observer gains a sense of interconnectedness with the whole planet, they start from establishing a mental connection with something familiar, as described by Russel Schweickart:

> *You finally come up across the coast of California, and you look for those friendly things, Los Angeles and Phoenix and on across to El Paso. And there's Houston, there's home... and you look and sure enough there's the Astrodome – and you identify with that, it's an attachment* (White 2014, pp.9).

When designing a VR experience, the story line should start from establishing a familiar connection for an immersant first, before extrapolating that feeling to the full planet. This connection should not only be established with a location on the globe when Earthgazing, but even earlier, at the initial part of the experience, inviting the immersant to a virtual environment representing a familiar setting, that the immersant can easily associate with and feel *at home.* In our previous studies, we found that the majority of confirmed awe-inspiring moments occurred when immersants had self-relevance, such as when selecting to visit a familiar location that held personal meaning (Quesnel and Riecke, 2018). It is possible that this effect carries into the experience of the OE.

3.5.4.5   Earthgazing perspective

Since there are multiple types of space missions, the Earthgazing could happen from three different perspectives: from inside a spaceship, from a spacewalk, and from the surface of the moon. Thus, it poses a design question for the VR experience – from which perspective should Earthgazing happen in VR to have the highest chances of achieving OE? The first scenario of Earthgazing from inside the spaceship has an advantage for a VR simulation, as having the cockpit in the view and serving as a foreground object would increase vection (the illusion of self-motion) (Howard and Howard, 1994). However, the reports of astronauts suggest that a spacewalk environment might be stronger in the ability to induce OE. Jack Lousma describes:

> *It's like a whole new world out there! Your perspective changes. When you're inside looking out the window, the Earth's impressive, but it's like being inside a train; you can't get your head around the flat plane of glass. But if you stand outdoors, it's like being on the front end of a locomotive as it's going down the track!* (White 2014, pp.40)

The third scenario of Earthgazing from the moon has been experienced only by a few astronauts, and they describe it as a different and stronger experience, as if the magnitude of the OE is proportional to the distances from the Earth. Michael Collins said "*There is definitely a different feeling. At 100 miles up, you are just skimming the surface, and you don't get a feeling for the Earth as a whole*" (White, 2014, pp.183)

Since VR allows us for more freedom in the design of the progression of the experience, we can incorporate any combination of these perspectives, possibly starting from a more familiar orbit perspective and seeing the interconnectedness of all countries, and then extrapolating the effect further while moving away from the Earth and developing a stronger awareness of how the Earth is one living organism. The opposite direction of approaching the Earth from distance can create an alternative narrative, where the immersant first will be introduced to the general idea of the fragility and unity of Earth, and then develop a more detailed and elaborated appreciation of it when Earthgazing from a greater orbital distance and noticing how a lot of the geographical locations are actually closer and more interdependent than we got used to think based on 2D political maps. The choice between these two progressions will have to be determined experimentally through user testing.

3.5.4.6 Priming and Inducing the desired state

To implicitly guide the immersant to the desired state, we can include an altered biofeedback that would aim to guide the immersant into a calmer and more introspective state. This approach was found to be effective when participants would hear a modified sound of their footsteps, that would imply that they are heavier or lighter than they actually are, resulting in a corresponding altered perception of their body-weight and an increased motivation to exercise measured through physical properties of their walking activity (Tajadura-Jiménez et al., 2015). In a different study, an altered heart rate as biofeedback in men affected judgment of attractiveness of females in pictures (Valins, 1966). Since outer space is a very quiet environment, the only sounds heard by astronauts (other than from inside the spaceship) are the sounds produced by their own body; as such, we can include a believable soundscape that integrates an altered breathing and/or heartbeat feedback designed to calm or excite the immersant.

3.5.5 Summary of Design Guidelines

The design of the experience should focus on facilitating a journey for the immersant that gradually prepares them for the climax of the experience and assist with the accommodation and processing of it. The VR creators should think beyond the VR component of the experience and thoughtfully design the pre- and post-VR environments as an essential part of the journey. The designers would have to work around the technical limitation of the technology, and utilize the scientific knowledge of human perceptual and attentional

processes along with artistic intuitions to "trick" immersant's perception and produce a compelling and impactful experience.

3.6 Evaluation Methods Design

One of the challenges that arises when we strive to design a VR experience that could give immersant a glimpse of an OE, is identifying methods that will allow us to determine whether (or to what degree) the created experience was successful in evoking a profound experience similar to OE. In this section we will analyze the described effects of OE and propose a number of methods that can be used to asses these aspects. Since OE is a very complex phenomenon, we propose to design a comprehensive system of multiple evaluation methods combining introspective, physiological, implicit attitudes and behavioral measures. Our transformative experiences framework outlines how a transformative experience such as OE can be assessed at different stages of the experience and what role VR can play in that process (Stepanova et al., 2018b). We suggest to conduct cued-recall debriefing (Bentley et al., 2005) after the VR experience with the participants, in combination with introspective open-ended interviews to look for constructs similar to the ones that astronauts describe in their interviews. Cued-recall debriefing is a situated recall method that captures on video the first-person perspective of the participant's experience in VR, and is often successful in re-immersion that results in reporting of affective states. Phenomenological interviews complement cued-recall debriefing: while cued-recall may provide insight into the moment-to-moment thoughts and feelings during system use, interviews provide more information on the participant's history and overall experience. Below we will outline the constructs to structure the analyses of the interviews as well as non-introspective methods of assessing some of them. We have summarized the proposed relationship between experiential components and correlates, cognitive constructs and outcomes of the OE in the Figure 3.1. The specific research tools proposed in this section are summarized in Table 3.1 and organized based on each tool and when to implement it.

When approaching the task of measuring OE, first of all, we need to differentiate between the spaceflight experience and the OE. Even though the OE as a phenomenon in its current description is directly related to spaceflights (or in some cases to jet or plane flights), there is no clear understanding of what experiential aspects of a spaceflight might be related to, or necessary for the experience of OE. Thus, we will analyze these aspects separately.

3.6.1 Experiential Components of a Spaceflight Experience

Frank White identified four main aspects of the spaceflight experience that we will discuss below: changed perception of time, changed perception of space, silence, and weightlessness (White, 2014, Chapter 3).
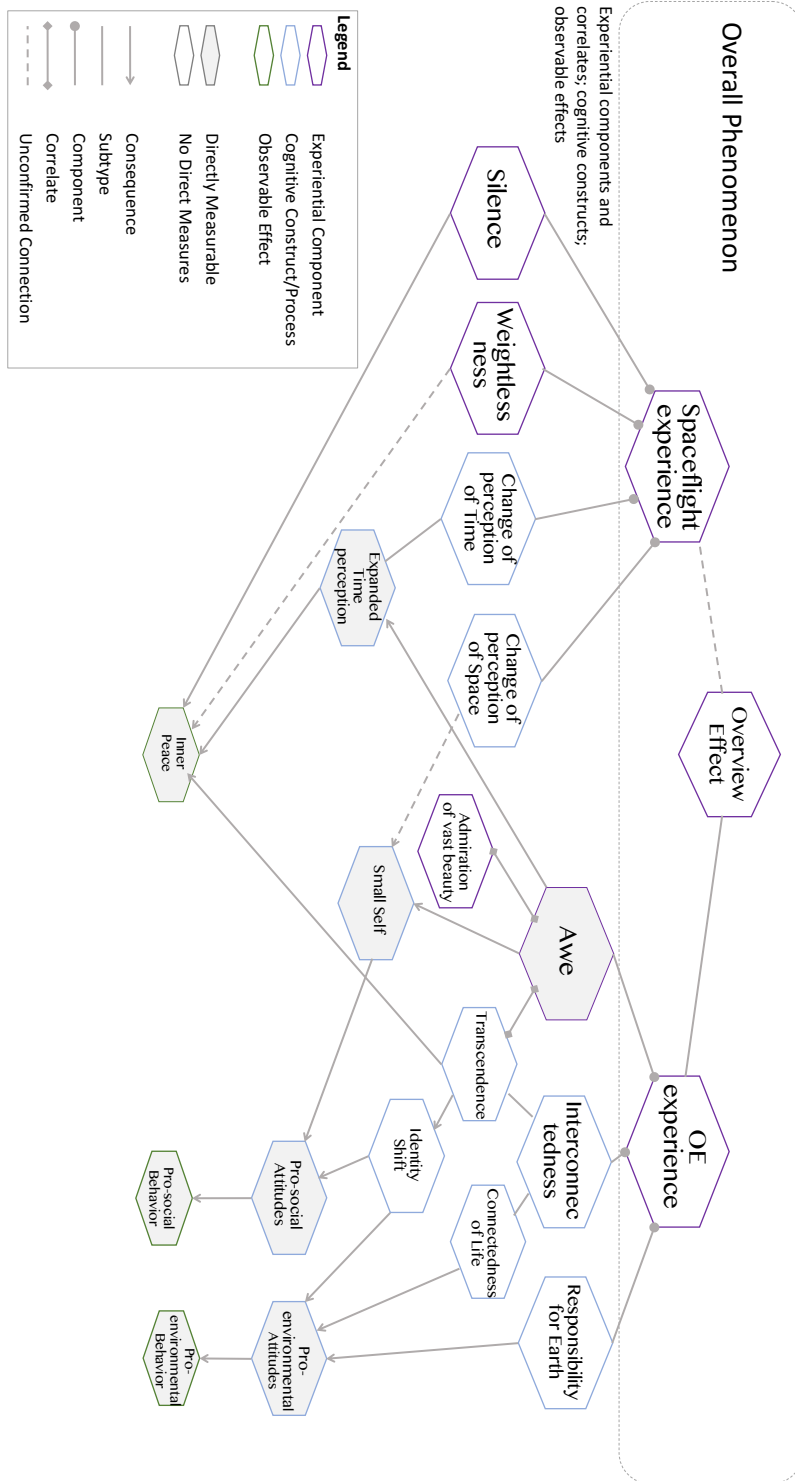
Figure 3.1: The cognitive constructs and outcomes of the Overview Effect

3.6.1.1 Changed perception of space

There seem to be two aspects of the changed perception of space: 1) a relative perception of one's individual position in space and 2) an acquired perception of scale and position of the planet in the universe and in relation to other terrestrial bodies, as well as the distances between different locations on Earth. Earthgazing astronauts often report how they notice how different places on Earth seem to be connected and how there are no boundaries between countries; we are all neighbors. This effect can be observed in interviews, but also measured quantitatively through implicit measures. Such evaluation methods can be borrowed from studies on the effect of cognitive maps on distance estimation(where a cluttered map would result in longer distance estimation) Thorndyke (1981). To adapt this method for our goal in VR, we will ask participants to estimate the distances between different geographical locations, especially between and within a country, before and after the VR experience. We expect the estimation of the distances to shrink after the VR experience if the immersant experienced the OE.

John Herrington described his altered egocentric perception of direction as follows: "*I was looking at my hands as I was moving along, looking up relative to the space station, and then instantaneously, I was looking down at the space station, and I hadn't moved. My mind was suddenly telling me I was looking down rather than up*" (White, 2014, p.20). This disorientation can be measured through interviews and cueing the estimated orientation of the participant. It can be induced through interaction of navigation interface and body position and visuals slowly drifting off from each other, like in redirected walking (Zhang et al., 2015).

3.6.1.2 Changed perception of time

Most straightforwardly, time perception is measured through asking participants to report a duration of certain stimuli. Thus, in our case we are proposing to query the participant after the VR experience to estimate how long they have spent in VR. However, there will be two possible explanations for an overestimation of time: the experience was found significant or emotional (Droit-Volet and Meck, 2007), or that it was uninteresting or unpleasant and time "dragged on" (Sackett et al., 2010). These will have to be disambiguated through interview data in order to be understood. Scott Carpenter stated:"*I felt a curious compression of time, as if the speed at which I traveled had some effect on the length of the moments I spent there and packed them too tightly on top of one another*" (White, 2014, pp.178). Interestingly, the research on the phenomenology of awe suggests that as an emotion, awe often expands individual's perception of available time (Rudd et al., 2012). Rudd's *et al.* study implements a number of measures of perceived time availability that we can utilize to understand perception of time in VR: 1) The perceived-time-availability index is a short Likert-scale embedded in a longer survey; 2) willingness to commit time to pro-social causes

(e.g. volunteering) can be compared to willingness to commit money to the same pro-social causes (e.g. charity); 3) choosing between experiential goods or material goods (e.g. concert tickets over a wrist watch). In Rudd et al. (2012) the measures were all done as a set of hypothetical survey questions, but we propose to modify this method to be presented as real choices to participants through deception: for instance, participants can be informed that they could enter a draw as a reward for their participation and offered to specify a preferred prize out of available material and experiential options; or they can be offered to leave their contact details for either a volunteer organization or a charity.

3.6.1.3 Silence

The silence experienced by astronauts is hard to achieve on Earth. Earth-bound experiences that would have a similar experiential component of pure silence could be scuba diving, caving (spelunking), and possibly sensory deprivation tanks. If the design of the VR experience strives to induce the experience of silence for the immersant, they can look into the role of silence and its psychological outcomes during caving and scuba-diving experiences to determine the appropriate measures for this experiential component.

3.6.1.4 Weightlessness

The phenomenology of experience of weightlessness hasn't been receiving a lot of scientific attention, due to the difficulty of achieving the experience of weightlessness on Earth. The closest studied experiences are the ones of flotation tanks. The sensory deprivation of flotation tanks submerse participants in a highly salted water, thus achieving a state close to weightlessness. A meta-analyses of 27 studies of flotation therapy supports its effectiveness for stress-management and well-being (Van Dierendonck and Te Nijenhuis, 2005). Besides most commonly reported relaxation, other effects such as altered state of consciousness, altered time-perception, and out-of-body experiences are also reported by individuals using sensory deprivation tanks (Kjellgren et al., 2008). Since the body of research on psychological effects of weightlessness is fairly limited and it's main effects intersect with other effects of OE, for the virtual OE experience we propose to add "weightlessness" as a category for analyses of the interviews of participants, but not add any separate directed measures.

3.6.2 Experiential Components and Outcomes of Overview Effect

Frank White identifies three main components of the OE: "*feeling of awe for the planet, a profound understanding of interconnectedness of all life and a renewed sense of responsibility for care of the environment*" (White, 2014, pp.2). We discuss below how different traits of the experience could be evaluated through different methods and at various stages of processing.

3.6.2.1 Emotional correlates

Awe: Awe has been described as one of the key aspects of the OE. Although emotion research into awe is still in the early stages, there has been progress in determining both constructs and psychophysiological correlates to an experience of awe. Awe is a subjective experience that many individuals find difficult to put into words, which highlights it's complexity. However, the body gives some clues as to when awe might occur. Among those clues is the sensation of "chills" (also seen in literature as "shivers", "frisson", "tingles"), and often their concurrence with visual piloerection, or commonly known as goose bumps ("goose flesh") (Benedek and Kaernbach, 2011; Grewe et al., 2009a; Keltner and Haidt, 2003; Nusbaum and Silvia, 2011; Stellar et al., 2017). Among the studies by Benedek and Kaernbach (2011); Quesnel and Riecke (2017); Sumpf et al. (2015); Wassiliwizky et al., (2017), there is overall a 40% rate of goose bump elicitation in participants who watched moving/awe-inspiring videos or VR as stimuli. The consistency of this rate means goose bumps (with concurring chills or not) may be experienced by some people but not others, or that lab-induced stimuli may elicit less intense awe experiences, theorized by Benedek and Kaernbach (2011), Silvia (2012), and Silvia et al., (2015). Other physiological measures may correlate with goose bump presence, such as heart rate variability (Grewe et al., 2009a), and skin conductance Chirico et al. (2017). The measures can be recorded along with goose bumps, and deep learning can be used to look for correlations and possible patterns of interest among multiple biosignals at once (Quesnel et al., 2018a).

Aside from psychophysiological measures, there are several studies that have analyzed awe-inspiring experiences into themes. Among these is the work of Gallagher and colleagues (2015), who used a hermeneutics exploration of syntax and language used during the experience of awe by astronauts during the OE. This textual analysis resulted in the creation of 34 consensus categories of awe, wonder, curiosity, and humility described by the astronauts in the texts. Such categories include: "Captured by view/drawn to phenomenon", and "Scale effects (feelings of the vastness of the universe or one's own smallness/insignificance)". In their study, the phenomenological interviews by participants who experienced a space simulation were compared to these categories and descriptions of the OE experience by astronauts, showing a significant overlap of the descriptions of awe. As demonstrated by Gallagher et al. (2015), the use of such categories of the OE and its features of awe and wonder are highly relevant for analyzing the immersant's experience in a VR simulated space environment.

Another interesting trait of awe is a "small-self" or "diminished self" (Piff et al., 2015; Bai et al., 2017) – which associated with the trait of humility, an emotion strongly correlated to awe (Stellar et al., 2018). When experiencing awe, one's focus shifts away from themselves, towards a greater collective. The cognitive construct of "small-self" can be covertly measured through asking participants to create a visual representation of themselves in the world,

specifically asking them to draw a picture of themselves in a simple environment and then the experimenter can measure the relative size one's self-representation in the relation to other objects in the environment (Bai et al., 2017).

Meditative State and Inner Peace: Edward Gibson described his experience of Earthgazing: "*You can see that a lot of things you worry about don't make much difference in an overall sense. The result is that you enjoy the life that is before you; you don't sweat so much about the next milestone... It allows you to have inner peace*" (White, 2014, p.41). This type of description of the OE suggests that the state achieved through experiencing the OE might be in effect similar to the states achieved through transcendent meditation. The inner peace in the moment can be measured through physiological correlates of meditation and relaxation, such as brainwaves (Cahn and Polich, 2013), heart rate variability, and breathing patterns (Peng et al., 2004; Peressutti et al., 2010; Cysarz and Büssing, 2005). Inner peace can also be measured through observation of participants' behavior before and after the experience, and coding the hectic, rushed vs. peaceful, relaxed movement patterns.

3.6.2.2 Attentional measures

VR provides the researchers with an easy access to the low resolution gaze data of the participants: even without an eye-tracker, the VR headset itself provides the head movement and position data that gives an estimate of where and how the immersant is looking. Scott Carpenter talked about his experience: "*I found it difficult to tear my eyes away <...> Everything is so new and awe-inspiring that is difficult to concentrate for very long on any one thing*" (White, 2014, p.29). By recording the head position data, we can analyze head movements and dwelling in a similar way as attention being measured with eye-trackers. If available to the researchers, than can use HMDs with built in eye-tracking system for even more precise measure. While normally complicated to acquire in a dynamic environment, attention data comes almost "for free" with the VR technology, however the data can be challenging to interpret as there is no singular interpretation of dwell time, thus additional information will be required for disambiguation of the results, which can come from the interviews. The smoothness of the gaze pattern could also indicate the calmness of the state of the immersant.

3.6.2.3 Interconnectedness

The feeling of interconnectedness has two components, which can occur together or as independent experiences: the realization of the interconnectedness of life on Earth, and transcendence of one self with the universe.

Interconnectedness of life: Don Lind, as many of other astronauts, described: "*You can't see the boundaries over which we fight wars, and in a very real way, the inhabitants of this Earth are stuck on a very beautiful, lovely little planet in an incredibly hostile space, and everybody is in the same boat*" (White, 2014, pp.43). When seeing the Earth as a whole,

astronauts come to realize how all of the living species are interconnected together. We can anticipate that this realization would lead to reduction of racial biases and acknowledging of interdependence of systems and events on our planet.

Transcendence: As in transcendent experiences, the OE leads to perceptions of one self's boundaries dissolving and instead one starts associating oneself with the whole world. As described by Russel Schweickart: "*And that whole process of what it is you identify with begins to shift. When you go around the Earth in an hour and a half, you begin to recognize that your identity is with the whole thing, that makes a change.*" (White, 2014, pp. 9)

Interconnectedness can be measured through linguistic analyses of the word usage in interviews with participants, e.g. comparing the frequencies of "I" vs. "us" or "everyone" etc. (Yaden et al., 2017b). Another method that can be used for tapping into the cognitive structure is implicit attitude measures (Wittenbrink and Schwarz, 2007). This class of methods is based on the assumption that our cognitive system consists of concepts that when having stronger connections between each other will produce faster responses when triggered one after the other or together. For assessing the interconnectedness experienced as a part of the OE, we can use an implicit association test evaluating the inclusion of nature in self (Schultz et al., 2004). For instance, pre- and post-test IAT was successfully used by Peck et al. (2013) to measure the reduction of racial bias after embodying an other-race avatar, and our pilot study of using the inclusion of nature in self IAT with an underwater VR experience (Stepanova et al., 2017) suggested that it might be a useful measure but it is prone to noise and requires a quiet, distraction-free setting, and as such won't be good a fit for studies run outside a lab environment.

3.6.2.4   Responsibility for Environment and Earth

Many of astronauts after traveling to space return with a compulsion to take care of our planet and it's inhabitants. Edgar Mitchell describes this state as:"*having this sort of explosive awareness that some of us had, this abiding concern and passion for the well-being of Earth*" (White, 2014, p.39). The sense of the responsibility for the Earth can be measured through observing pro-environmental behaviors. For example, in Ahn's study of a VR experience promoting understanding of the concern of deforestation, the experimenter was "accidentally" dropping a glass of water and observing how many napkins participants will use to wipe the spilled water (Ahn et al., 2014). Similarly, we can offer the participant a glass of water and observe if they will use a reusable of disposable cup, or kindly ask them to throw out some trash on their way out and record if they went through the effort of sorting the garbage into the recycling bins. These measures will, however, be dependent on individual's beliefs of what constitutes a pro-environmental behavior.

Moreover, given the feeling of interconnectedness associated with the OE, we would expect to observe increased pro-social behavior, that can also be assessed with observational measures. For instance, in Rosenberg's study on inducing pro-social behaviors through flying

like a superman in VR, they were observing how quickly participants would reach to help the experimenter pick up the pens that he dropped, and found that both the number of pens was higher and the reaction time was slower on average in the superman condition comparing to the control (Rosenberg et al., 2013).

3.6.3 Considerations to take when applying the measures

3.6.3.1 Individual Differences

It is important to note that even though the OE experience seems to have common underlying traits, it is being interpreted differently by each individual (White, 2014, pp.11). For instance, Don Lind explained that religious astronauts and space-travelers often tend to describe OE in religious terms, while people with no religious background interpreted it though different terms, often having nothing to do with spirituality (White, 2014, p. 23). Some astronauts were associating the effect of the spaceflight experience with experience of traveling to foreign countries. Joseph Allen stated "*I found that travel in space was a grand extension of the principal that taking a journey was a good thing*" (White 2014, pp. 205). Understanding whether participants have a substantial amount of traveling experience to extrapolate from will allow us to better interpret their interviews. Thus, for such a complex experience it will be especially important to collect extensive demographic data on the participants in order to be able to interpret their self-report data in the context of their individual background.

3.6.3.2 Time required for Accommodation of The Experience

Not all of the astronauts report on having a profound change in their worldview, which could be because not everyone experiences the OE, or some people choose not to discuss it, or it could take month or years to accommodate the experience, as was suggested by Charles Walker and Edgar Mitchell in their interviews with Frank White (White, 2014, p. 41). When taking measures aimed to asses a cognitive shift or behavioral change we need to be mindful that these changes require an accommodation period, which could be different for different people, and, thus, we may miss the positive effect, if we were taking the measure too soon.

3.6.4 Summary of Evaluation Methods

This section and Figure 3.1 illustrates how such a complex phenomenon of the OE requires an elaborate system of various evaluation methods assessing it's immediate emotional components (e.g. admiration of the vast beauty of Earth) as well a more long-term effects such as cognitive shifts (e.g. identity shift, expansion of time perception) and psychological (inner peace) and behavioral (pro-enviromental behavior) outcomes. Only by combining multiple evaluation methods assessing different constructs and components of the OE we would be

able to develop a comprehesive understanding of the unfolding of the phenomenon. However this conceptual framework illustrated in Figure 3.1 will need to be further refined and verified through additional research determining the exact relationships and interdependence of the discussed constructs. The specific methods of evaluation that we have proposed in this section and summarized in Table 3.1 can be substituted by alternative methods assessing the same constructs, however we insist that in order to be able to infer that the OE was experienced, majority of the constructs will need to be assessed individually first and then triangulated. The Table 3.1 is structured around the research tools rather than the constructs in order to provide a summary of what each tool can allow to measure and what it can't.

3.7   Existing Implementations

There were a number of attempts to elicit the OE using immersive technology. For instance, Chirico et al. (2018a) investigated how three virtual environments presenting vast stimuli, one of which was the view of Earth from space, are able to induce the sense of awe in participants. Their results indeed show that awe-inspiring virtual environments were more likely to induce awe (measured through self-report questionnaires) than the control environment of a green field. Reinerman and colleagues (2013) created a mixed reality space capsule through which participants of their experience were passively observing an Earth moving away until turning into a blue marble and a deep space view of a path through stars. The phenomenological interviews showed more experiences of awe in the Earth condition, than in deep space, and EEG recording proposed brainwave traces of the experience of awe. Gallagher et al. (2015) describe a number of virtual simulations of a spaceflight; their resulting textual analyses of participant interviews showed similarities to spaceflight experiences by astronauts. This indicated some effectiveness of inducing an experience similar to the OE. We used an artistic approach to a VR experience inspired by the OE, and created a physical/virtual environment called *AWE* (Quesnel et al., 2018b; Stepanova et al., 2018c) that has been demonstrated at multiple conferences and community events. Early results are encouraging in both it's potential to improve well-being, and to induce a cognitive shift towards the sense of global interconnectedness.

All of these implementations show indications that an experience similar to the OE may be achievable here on Earth through immersive technology. However, most of the results can be considered preliminary, and more research and design iteration are required in both how experiences are created, and how they are being evaluated. Simply letting immersants experience a VR environment visually representing outer space is engaging, but doesn't seem to produce a profound experience that could be identified as the OE. A more thoughtful design of the immersant's journey using prerequisites (e.g. privacy) and facilitation of transitions through the stages (e.g. from fear to awe) are necessary. At this

Table 3.1: Summary of proposed evaluation methods

When	Research Tool	Analyses	Immediate Construct	Who used the tool
post	Cued-Recall Debrief	Ind. position in space	Changed space perception	n/a
post	Phenomenological interview	Environmental systems	Global interconnectedness	n/a
		No country boarders		n/a
		Self-identifying	Shift in identity	n/a
		How long was the experience?	Changed time perception	n/a
		Textual analyses	Concepts similar to astronauts	Gallagher et al. (2015)
		Linguistic analyses "I" vs. "Us"	Identity shift	Yaden et al. (2017b)
prior & post	Geographical dist. estimation	Shrinkage of dist. est.	Space perception	Thorndyke (1981)
			Global interconnectedness	
post	Choose prize for a draw	Experiential vs. Material	Changed time perception/awe	Rudd et al. (2012)
	Leave contacts for organization	Charity vs. volunteer		
prior & post	Draw yourself	Relative size	Small self	Bai et al. (2017)
during	Wearable camera	Goose bumps	Awe	Quesnel and Riecke (2017)
during	Heart rate sensor	Pattern	Awe	Grewe et al. (2009a)
			Inner Peace	Peng et al. (2004)
during	Skin conductance sensor	Spikes	Awe	Chirico et al. (2017)
during	Breathing sensor/mic	Pattern	Inner Peace	Vidyarthi et al. (2012)
			Awe	Shiota et al. (2011)
prior & post	Observation	Pattern of movement	Inner Peace	not found
during	Eye- or head-tracking	attention, dwell time	Admiration of beauty	alike Massaro et al. (2012)
		gaze pattern	Inner Peace	not found
prior & post	IAT racial bias	Other race and self	Identity shift	Peck et al. (2013)
prior & prost	IAT nature in self	Nature and self	Pro-environmental attitudes	Schultz et al. (2004)
post	Offer water	Reusable vs. Disposable cup	Pro-enviomental behavior	alike Ahn et al. (2014)
	Ask to throw out garbage	Recycling		
post	"Accidentally" drop pens	RT, and N of picked up pens	Pro-social behavior	Rosenberg et al. (2013)

moment, we, as a scientific community, are still far from understanding how to induce the OE on Earth. However, inducing some degree of it's components, such as awe and interconnectedness, have indeed been demonstrated in some participants.

3.8   Conclusion

The OE is a fascinating, albeit extremely rare phenomenon that has been gaining more public and scientific attention in recent years. Making the OE more accessible to people can allow us to facilitate a restructuring of the value system in individuals and society. It could be an essential step in addressing major social and environmental issues that our world is facing, as well as individual psychological struggles. Even though some fundamental work has already been achieved in generating an Earth-bound OE, we remain far from bringing an authentic, profound experience of the OE to the public. This ambitious mission to comprehensively understand and create an OE will require an interdisciplinary team of researchers, VR developers, artists, and clinical psychologists that iteratively develop and study profound immersive experiences, and their effects on people.

In this paper, we explain what the OE is, and how it has been evaluated. With the understanding of the OE's significance in place, we then propose a series of concepts and guidelines for designing and evaluating the OE experiences in VR to make this profound experience accessible to researchers and the general public. We invite our peers to utilize, explore, and expand on these concepts and guidelines for both the design of the OE experience and the proposed evaluation methods. It is important to recognize the need for these concepts and guidelines to be validated and refined through purposefully designed studies with VR experiences. We encourage the community to become engaged in a dialogue about the conceptual structure and the methods for creating emotionally profound, positive and transformative experiences like the OE on Earth, with the use of modern technology. The OE is an extraordinary and complex phenomenon, but through an iterative collaboration between VR developers and researchers we might be able to recreate and understand it better, making this profound experience accessible to people around the world.

Chapter 4

Creating AWE

Artistic and scientific practices in research-based design for exploring a profound immersive installation

4.1 Abstract

The paper describes *AWE* (2018), an immersive mixed and virtual reality installation designed to elicit feelings of awe and wonder. Experiences of awe are found to prompt feelings of interconnectedness and an improvement to perceived well-being. To address the challenging prospect of designing for a specific emotional experience in a wellness application, we combined artistic and scientific practices through a research-based design process in order to identify awe-inspiring traits, generate a typology of awe, identify emotion validation techniques, and undertake iterative prototyping of the installation directly with participants. The resulting installation integrates a pre-VR mixed-reality experience to prime immersants for openness to the experience, followed by an immersive VR environment, and it uses a novel, custom interface for intuitive hands-free navigation. Our methods involve phenomenological interviews and physiological sensors to evaluate the evoked emotional experiences, which then inform design decisions to improve the system. Additionally, we integrate bio-responsive elements into the environment to further personalize the experience. Results suggest that *AWE* can elicit the target emotional experience of awe, prompt a transformative experience, and improve well-being in some participants.

4.2 Introduction

Awe-inspiring experiences can lead to shifts in perspective, changes to moral attitude, and in how people see their relationship with the world (Keltner and Haidt, 2003). Even though an agreed-upon empirical definition of awe is challenging, there is a large body of literature outlining its common traits, characteristics, and outcomes. Awe is a component of a transformative experience where an individual feels part of a greater collective, a sense of belonging, and greater purpose (Stellar et al., 2017). Furthermore, awe tends to transcend

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the attention beyond the individual self and towards the environment, providing therapeutic and social benefits; a study by Rudd, Vohs, and Aaker (Rudd et al., 2012) found that awe was correlated with increased willingness to volunteer, a preference for experiences over material goods, expanded time perception and increased life satisfaction. Being awe-inspired is also good for our physical being: of the six positive emotions measured, awe was found to be the strongest predictor of reduction in inflammatory cytokines (Stellar et al., 2015), which are responsible for the initiation and persistence of pathologic pain (Dinarello, 2000).

Despite its wellness benefits, awe and its cousin emotion "wonder" are rarely experienced due to specific conditions they require, such as an attitudinal openness to a new experience and the presence of astonishing visuals, like landscape vistas (Shiota et al., 2007). While lacking spontaneous awe-inspiring experiences, we might look to the use of technology to create conditions for delivering these experiences. Throughout the history of technology development, there have been many attempts to induce profound emotions via different mediums. Now, Virtual Reality(VR) technology provides new opportunities.

VR has been found to elicit responses in participants similar to those in real-life situations and is regarded as a compelling tool for psychological research, especially in studying situations difficult to replicate in physical reality (Wilson and Soranzo, 2015). To understand how profound emotions can be elicited in VR, and why VR as an immersive media is conducive to awe-inspiring experiences, we explain the transformative potential of VR. This multi-sensory, often highly interactive, platform enables "presence" in the virtual environment – to the extent that the body and mind believe what is happening is real (Usoh et al., 1996). Each of our senses forms our perception, and based on our perception our mind tries to construct a consistent model of the world that guides our cognition, emotions, and behavior. In immersive VR, we are constructing an extension to our perceived reality, expanding our mental model. According to Coelho *et al.* 2012, VR is unique from other communication systems like cinema and television in that it combines immersion delivered through immersive displays such as a head-mounted display (HMD), with deliberate actions placed upon the virtual environment by the immersant (participant). While imaginative immersion can occur through reading books, watching movies, and playing video games (Ermi and Mäyrä, 2005; Vidyarthi et al., 2012), VR is also physically immersive through augmentation/replacement of stimuli to an immersant's senses via the VR technology (Sherman and Craig, 2003), and sensory immersive through blocking out stimuli from the physical world (Ermi and Mäyrä, 2005; Vidyarthi et al., 2012). The ability to feel immersed and to act upon the environment through interaction leads to a sense of "being there", and classifies VR as an experiential interface (Riva et al., 2006).

Given VR's ability to make impossible or rare real-life experiences virtually possible and accessible, we look to what many astronauts and philosophers regard as the most awe-inspiring experience of all time: the profound experience of seeing the Earth from space – a phenomenon called the "Overview Effect" (White, 1998). The Overview Effect is a cognitive

shift that astronauts go through when they observe the Earth from space; in witnessing how beautiful and how fragile the Earth is, a yearning arises as a united species to protect our home planet. The feeling of intense awe is central to the Overview Effect experience, which is comprised of awe elicitors like the perceptual traits of vastness and beauty, and also a conceptual sense of "wholeness" and "unity" arising from seeing the entirety of the planet (Yaden et al., 2016). As revealed in detailed interviews with retired NASA astronauts, this extreme awe experience directly influences belief and value systems, resulting in perceived improvement to their psychological well-being (Nezami, 2017). We were inspired to make an immersive reality installation that may potentially influence well-being, and we will describe the motivators for our design decisions influenced by the Overview Effect and awe.

4.3   Research-Based Design

4.3.1   Motivation for the Design

Our overall goal with *AWE* as an immersive reality installation is to **evoke a sense of awe and wonder that may lead to well-being benefits and increased sense of interconnectedness** for some immersants. We aim to achieve this through designing known awe-inspiring stimuli, prompting moments of introspection through a narrative, and prepare and prime immersants to be open to the experience through a safe, physical pre-VR environment.

While VR artwork is becoming more prolific, we have not yet reached a mass quantity of VR worlds that synthesizes our knowledge on how to design emotionally profound immersive experiences. This is especially true when attempting to design for a very specific emotional experience, like awe. Although some best practices exist for designing around technical difficulties of VR like motion sickness, narrow field of view, and navigation through large virtual spaces, there are still a few known and agreed-upon content creation practices. To make the most informed design decisions in order to understand how a VR experience might elicit awe, we used research-based design (RBD). Whenever possible, design choices centered around the human experience become the best evidence available to us; this is especially important in maximizing VR's transformative potential. Embracing methods from social sciences (Leinonen et al., 2008), RBD is particularly suitable to design of tools and systems for complex social systems, while it may not be required for some other design goals. As an iterative design process, RBD consists of four phases that can be concurrent or overlap: 1) contextual inquiry, 2) participatory design, 3) product design, and 4) prototype as hypothesis.

4.3.2   Phases of RBD

We began the RBD process with **contextual inquiry** – an exploration of the design challenge. This involves a comprehensive review of literature surrounding the phenomenon of
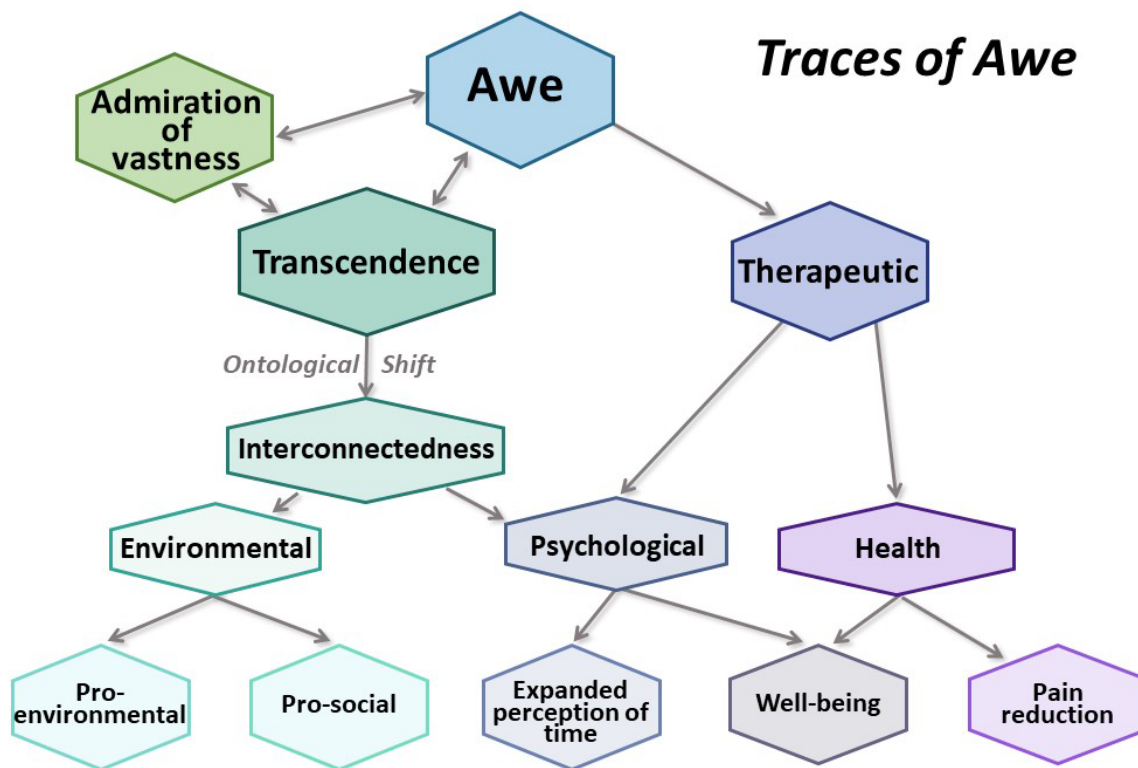
Figure 4.1: The many components and outcomes of an awe-inspiring experience.

awe and previous work on designing affective immersive experiences. Understanding what awe is, and is not is key, with Gallagher *et al.* 2015 forming a working definition of awe: "*a direct and initial experience or feeling when faced with something amazing, incomprehensible, or sublime*" (p. 6). Gallagher *et al.* created this definition through textual analysis of thousands of astronauts and study particpants awe-inspiring accounts, and in integrating empirical research on awe. We created a typology of awe (Fig. 4.1) to explore the outcomes and the variety of awe experiences immersants could have, many of which are still emerging as our use of technology increases.

As discovered from the literature review, awe is a profound emotional experience usually elicited through aesthetically appealing vast natural stimuli, like landscapes or vistas (Shiota et al., 2007). Previous work by Chirico *et al.* 2018a studied whether scenes of nature in VR could elicit awe, with findings demonstrating that environments depicting forests, mountains and the Earth from space successfully elicited awe. In the study of aesthetic elicitors of awe in VR and the role of interactivity, our own inquiry of research indicated that awe could be elicited in VR when participants selected world travel locations, which also included seeing the Earth from space (Quesnel and Riecke, 2017). These initial studies confirmed the hypothesis that VR could elicit awe, and also revealed limitations in immersive systems that actually inhibit awe, like hard to learn VR interfaces for navigation that can distract from the experience or even break presence.
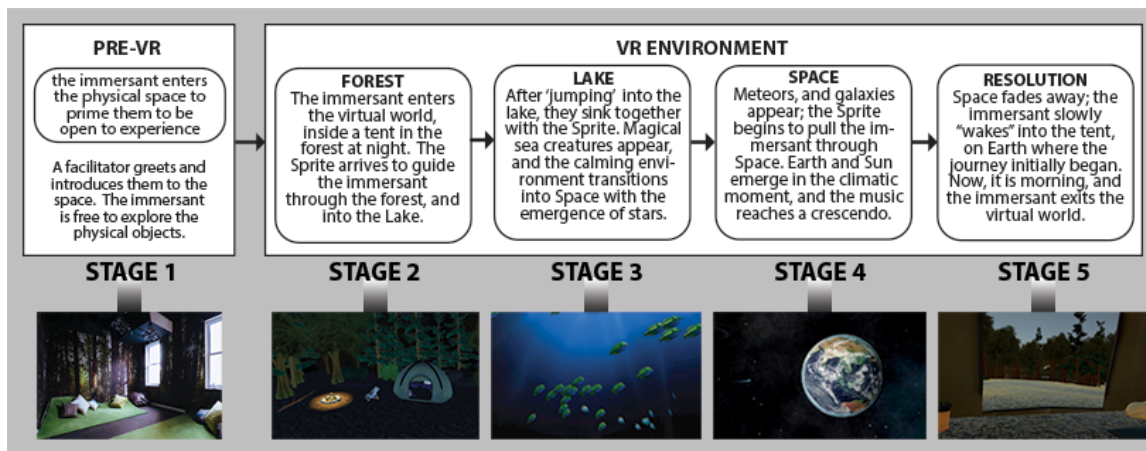
Figure 4.2: The five-stage journey the immersant proceeds through, starting with the Pre-VR environment, which blends into the VR environment.

Contextual inquiry also involves looking to inspiration from art and media. In designing the initial audio and visuals for our installation design, we draw knowledge from immersive installations in a gallery environment. An early, memorable system is *Osmose* (1995) by Char Davies, which involved aesthetic, spatial, and physical elements that lead to shifts in consciousness and profound emotional experiences (Davies and Harrison, 1996). Davies describes that specific design decisions, like an abstract environment combined with an embodied reliance of breath and balance allows an immersant to have introspective emotional experiences; a similar affect is observed in *Pulse Breath Water* (Prpa et al., 2018). Anecdotally, many media and immersive artists when exhibiting their work report similar findings of abstract environments leading to intense emotional experiences.

Narrative is also a factor in generating an emotional response; Gorini *et al.* 2010 found that narrative affects both self-reported emotions and physiological responses indicative of emotion. Again, storytellers and filmmakers who engage in narrative design have emphasized the importance of narration in immersion and emotion, with many frameworks developed as a result. At *SIGGRAPH* 2016, we tracked immersant reactions to *Pearl*, an immersive VR installation with a structured narrative depicting a coming of age story and selflessness between a father and daughter. The creative team followed a cinematic framework for the narrative, intuitively guiding design decisions (Osborne et al., 2016). We saw immersants visibly moved to tears, and others expressed how the experience facilitated affection for loved ones. As learned through *Pearl*, the intuition of artists and designers must be considered in our RBD process, as the tacit knowledge developed by practitioners is valuable.

With *AWE* we use research together with art and design intuition in a **participatory design** process. This involves 1) inviting practitioners of media arts and design to participate in the studies; 2) inviting the participation of individuals identified as the end users/immersants, like those who express an interest in using technology to connect to

nature and humanity. Together, these communities bring valuable insight into the design, informing how the affordances of the immersive VR technology come together with aesthetics and narrative for an authentic emotional experience. Through participatory design, we balance returning participants with naive participants in prototype installation iterations. These iterations directly lead to the **product design** phase, where we formalize the prototype and use this version of the design to run empirical studies using traditional mixed-methods, combining physiological and behavioral data collection with phenomenological interviews and observations. We then analyze the data to reflect on the design in the **prototype as hypothesis** phase, to see if our current design supports our goal of creating an awe-inspiring experience potentially leading to an increased sense of connectedness and improved sense of well-being. This allows us to rigorously validate the design decisions and artistic intuitions that went into creation of the prototype as well as identify new areas for improvement and further investigation. At any point during this process, we often go back to an earlier phase in order to iterate and reflect upon the design. We are currently on our fourth prototype of the installation after completing a pilot experience, followed by three full prototypes in 2017.

4.4   Development and Design

4.4.1   Summary

AWE (2018) is an immersive VR installation with a custom interface for intuitive navigation (for video, see `http://ispace.iat.sfu.ca/project/awe/`). Emotion-evoking audio and visuals are chosen for their potential to elicit awe and wonder. Through a physical mixed-reality environment that blends into a HMD VR environment, an immersant proceeds through five stages of the journey (Fig. 5.2). A mystical "Sprite" character sparks curiosity, and performs as a guide on a journey through Forest (Earth), Lake (Water), and Space, whereupon a climax presents an incredible image of Earth, evoking feelings of awe and connectedness. We detail the features of this system in the following subsections.

4.4.2   The Immersive Journey

The experience begins inside a physical, mixed-reality environment designed to calm and ready the immersant (stage 1). This environment consists of projected visuals wrapped on multiple walls, soothing audio, and physical objects mirroring those in the virtual world. This stage is aimed at helping the immersant become open to the experience. Next, immersants are seated on our hands-free navigation interface, and wear a HMD with headphones for a 6 DoF, immersive VR experience. The first scene is set inside a tent in the middle of the Forest (stage 2). The Sprite, a mystical being, appears and guides them through the Forest. The immersant is free to explore the environment, while the Sprite gently prompts them into a lake, a step requiring a leap of faith and trust. Upon entering the water (stage 3),

the immersant gradually sinks with the Sprite into the depths where magical sea creatures venture. Soon, stars begin to appear, and the water opens to a portal into Space (stage 4). Sprite looks similar in appearance to stars in Space, and in the ultimate reveal, the Earth comes into focus with the Sun illuminating the planet. After reveling in the beauty and vastness of our planet, the immersant's vision recedes, and they awaken at their campsite on Earth (stage 5), where it is now the start of a new day.

4.4.3 Physical Mixed-Reality Environment for Privacy and Emotional Priming

Most VR installations begin with the facilitator explaining how to use the equipment, and once the instructions are understood the immersant is expected to somehow teleport into the virtual world and engage with the environment. This first impression often leads to the perception that the experience is solely a demonstration of the technology. Moreover, wearing VR equipment can place the immersant in a somewhat vulnerable position, unaware of their physical surroundings, often self-conscious about their appearance; these concerns together naturally reduce the chances of evoking profound emotion. Furthermore, we found awe-inspiring experiences are usually a result of a meaningful journey and anticipation, such as climbing a mountain before the reward of picturesque views. It would be unnatural to expect an individual to be suddenly transported from their regular routine to a new environment, and instantly develop a profound emotional response to it.

Building trust in the immersive system and openness to the experience would be important for the elicitation of profound emotions. We focus on designing an entryway that mimics a meditation lounge as the first impression for the immersant. They then get comfortable inside a private physical space, consisting of a dark tent with mood lighting and projection of stars. Here, the immersant can be expressive and relax without concerns over being observed. This setup also addresses our goal of having an explicit transition from busy daily life, into a different, mystical space which prepares them for the virtual environment and the new experiences that may happen inside it. This pre-VR provides a space to slow down, develop a reflective state, and build the anticipation for the forthcoming experience; such a gradual transition into the virtual world from the physical environment has been shown to aid in achieving presence and immersion (Steinicke et al., 2009) as well as forming a participatory ritual for participants that can assist in introspective experiences (Kitson et al., 2018b). In testing a variety of pre-VR physical environments, the most well-received environment was a replica of a campsite that contained meditative elements and a projection of a nature scene; *"I was really relaxed, the vibe of the setup, I am busy so I wanted to relax. It let me do that."* – P#3, Pr2 (Participant #3 during prototype #2). *"The room is for me to calm down, prepare for the VR experience... I really liked that VR experience."* – P#6, Pr2.

4.4.4   Artistic Design

Based on the contextual inquiry phases of the RBD process, we discovered that abstract, beautiful aesthetics that feel "mystical" prompt a sense of wonder and curiosity. Such aesthetics in a physical and immersive environment suspend the immersant's disbelief and open them to the experience. We identified and tested design recommendations for fostering curiosity, imaginative immersion, and ultimately awe:

1. **Magical realism**: evades a violation of expectations of the real world, and thus promotes suspension of disbelief, imagination, immersion, and "presence", while maintaining some level of realism to create familiarity. Magical realism was likened to fantasy genres in our user studies.

2. **Ethereal elements**: the immersant is drawn to glowing objects meant to capture their attention as affordances. Additionally, they see fantastical creatures and enter a portal into Space. We use abstract visuals because during the contextual inquiry we were inspired by the 2015 video game *Ori and the Blind Forest* (Moon Studios, 2015), a dreamy environment that creates a sense of magic. The 2012 video game *Journey* (thegamecompany, 2012) also uses abstract, dreamlike audio and visuals to allow for the construction of one's own experience based on minimal information. This trait in *Journey* was discussed by individuals in our participatory design process to be incredibly immersive.

3. **Diffused lighting**: overall lighting is soft and cinematic to set the mood of the environment, and is reminiscent of scenes from fantasy genres.

4. **Subtle movement**: movement of virtual objects, and pacing of the environment is subtle as to reduce motion sickness. Sudden speed changes are used only with purposeful transitions designed to stand out and bring awareness to the immersant; for example, the jump into the Lake during the stage 2 to 3 water transition.

AWE uses colour to create distinct "moods" within each stage of the journey (Figure 4.3). Colours are understood to elicit specific moments of affect, contributing towards an overall mood (Shimamura, 2013) which we often see in films: cinematographers often use shades of violet to promote a sense of mystery and fantasy, while warmer blues are often regarded as calming; warm yellow and orange communicate warmth and friendliness. We strategically used cinematic colour in addition to the described aesthetic design elements for target affect. Immersants commented that the aesthetics led to a sense of immersion: *"It was very beautiful, all the environment and sounds. I loved it. The visuals were very good, I was immersed."* P#9, Pr2. Some used terms like *"the magic forest"* (P#1, Pr2) to describe the aesthetics.
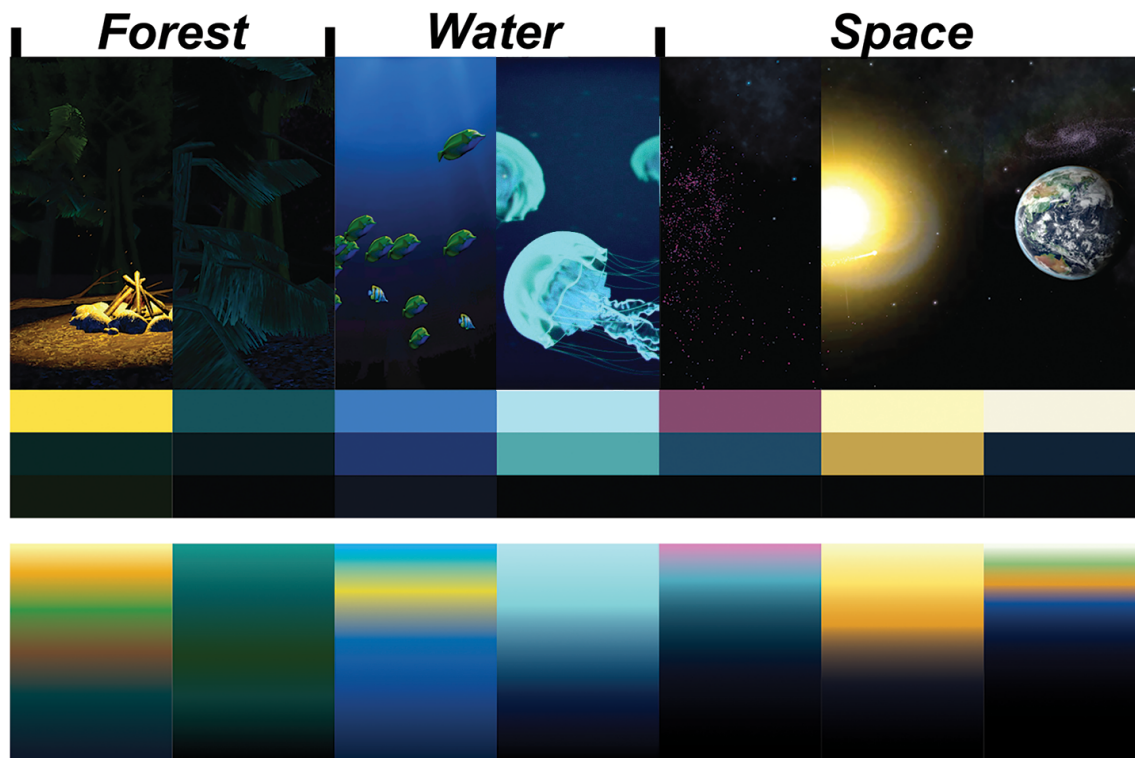
Figure 4.3: The colour mood journey of AWE in the virtual environment.

4.4.5 Soundscape

To better understand the emotion of awe, studies have explored the relationship of music listening and awe elicitation (Lundqvist et al., 2009). Panksepp found that familiarity with music pieces influenced the occurrences of chills (a marker of awe); music perceived as sad/melancholic evoked more chills than those perceived as happy/excited; music with emotion-eliciting properties (i.e. containing crescendos), triggered peaks in chill responses (Panksepp, 1995). Since a large body of research on emotion (especially awe) explores the connection of profound emotions and music, we paid special attention to the design of the soundscape.

The audio in *AWE* graduates from a meditative, harmonious soundtrack in the pre-VR environment to melodious in the VR environment. In the Forest, we hear the Sprite's ethereal vocalizations and woodland ambiance (positional audio). During the Lake transition, the immersant hears a splash, and the soundtrack changes to a hypnotic beat with underwater distortion effects. Chimes alert the immsersant to a pending transition, and in Space, the soundtrack is dominated by sub-bass intermixed with a bright lead pad. The climax consists of a sonic boom with reverb upon the appearance of the Earth; an ambient calming track guides the immersant back to the Forest soundscape. In our most recent study, we used a customizable soundscape where immersants individually pre-selected a music track.

This self-selected track was added between Forest and the Lake stages, triggered as the immersant traveled through the Forest, reaching a climax when jumping into the Lake. This climatic moment was chosen due to immersants in previous user tests describing it as a "pivotal" moment in the journey. Because music preference is a highly individual matter, self-selected music in studies is a reliable manner of triggering intense emotions (Thaut and Davis, 1993).

4.4.6 Narration and Guided Affordances

We created a mystical character, "Sprite", (for video, see http://ispace.iat.sfu.ca/project/awe/) revealed in Space to be a young star curious and compassionate towards the world. Sprites have knowledge of various portals from Earth to Space, and upon moving leave a stardust trail, subtly inviting the immersant to follow and establish a friendly connection. In this sense, the Sprite also acts as an affordance. There is no dialogue in the virtual environment, but there are triggers that call specific actions, such as bio-responsive elements reacting to breathing (see section H), and Sprite movement triggered through proximity. These subtle actions are meant to provide "a-ha" moments, where immersants are rewarded for their curiosity and self-reflection. *It feels very playful: the pace of it's movement, and it's up and down, it's almost like it is talking to me"* (P#1, Pr3). Prompts in *AWE* are meant to allow for inner reflection. One such prompt is when the immersant must trust the Sprite and take a leap of faith to follow it into the water. The water's surface appears eerie, but upon submersion, the sensation of floating, the lake creatures, and melodic audio is a reward. Several immersants spoke about having a fear of water, or being afraid to jump in the Lake but doing it anyway. *"All your muscles contract, it's almost, you try to hold yourself tight"* (P#2, Pr3). We observed them sharply inhaling upon landing in the water, then visibly relaxing once they realize nothing bad happens. During all prototype phases, some immersants described a wish to jump into the water well before the Sprite guides them there, and feeling a payoff when they take the leap. *"I wanted to jump in the lake and it was great to do it. A wish come true."* (P#6, Pr1).

4.4.7 Interface for Intuitive Navigation

In the first three prototypes, for intuitive navigation we used a custom hands-free interface that uses body-leaning cues to propel through the virtual environment. This leaning-based interface allows for a more natural locomotion compared to standard interfaces, like joysticks and teleportation (Kruijff and Riecke, 2017). This interface also reduces the potential risk of motion sickness caused by the conflict between visual and vestibular cues (LaViola Jr, 2000). We used a rotating swivel chair, as it is comfortable and safe, reducing a fear of falling compared to risks when standing upright and losing balance. However, this set-up was seldom able to induce the sense of floating that we wanted to achieve in stage 3 and 4 of the VR experience, and immersants reported that it was difficult to control their speed. In

Figure 4.4: An immersant with the custom navigation interface.

our latest prototype, we are using a custom interface called the Limbic Chair that supports each thigh in a way that allows legs to move independently (Fig. 4.4). Sensors in the chair are mapped to navigation controls in the virtual environment so that the immersant may steer gently with their legs and torso. The main benefit to going hands-free with a navigation interface is that it allows us to more closely mimic how we move in real life, based on how the brain and body's nervous system co-function. Limbic Chair designer Dr. Patrik Kunzler states that two neurological pathways exist in our bodies: hand-eye coordination (upper body, for complex tasks) and peripheral vision-spine coordination (lower body, for locomotion). By allowing the lower body to perform the locomotion and navigation, our mind is free to focus on mental tasks and observations of the environment Patrik Kunzler (2018). Additionally, immersants report feeling less motion sickness with this system, and also have experienced a sense of floating, our desired targeted sensation.

If interaction in the virtual world is poorly designed, it can negatively influence affect in the experience (Riva et al., 2007). In this context, an objective of *AWE* was to provide an intuitive form of interaction to give immersants a sense of agency through acting upon the environment. *AWE's* virtual world comprises of different levels of constrained interactivity, and this creates balance between agency and the guided narrative. The Forest (stage 2) contains the most unconstrained interactivity, with the ability to freely explore the envi-

ronment. Colliders are in place for realistic interaction with objects, and the immersant is prompted forward using affordances at various checkpoints. In contrast, the Water and Space environments utilize constrained movement around a defined but invisible trajectory; this way, the important transitions and climax are not missed because the immersant's attention is elsewhere.

4.4.8 Bio-responsive Elements

In the latest version of the prototype, we are adding bio-responsive elements into the environment that react to the breathing pattern of the immersant. For instance, an element will be a jellyfish in the Lake that expands with an inhale, then contracts and floats upwards with an exhale. These elements are added as an artistic form of bio-feedback that aims to help the immersant connect to their body and feelings. We will test these elements to see how noticeable they are, and if they facilitate introspection versus become a distraction.

4.5 Experience Evaluation and Validation

As an integral part of the RBD process we have also been iteratively developing a set of evaluation methods we use to test, validate, and improve our design decisions. We are following the transformative experiences framework (Stepanova et al., 2018b; Gaggioli, 2016) to understand the progression of the immersant's experience, and validate that the design decisions made in creation of *AWE* are successful at inducing a positive and profound experience. Through the development of the system, we ran user tests with the very community that will use the system (participatory design). In this section, we describe the evaluation methods and illustrate them with some results. The in-depth analysis is outside of the scope of this paper, and can be found in our upcoming publication Stepanova et al. (2018c).

4.5.1 Phenomenological Interviews

4.5.1.1 Cued-Recall Debrief

Immediately after the immersive experience, an immersant undertakes a cued-recall debrief, (Bentley et al., 2005) which entails watching a screen recording of their journey and describing what they experienced at notable moments. The interviewer may prompt the immersant with questions to obtain insight into particular behaviors that they notice. With the aim of 're-immersing' an individual into their experience by watching it, this method is less prone to recall errors than semi-structured retrospective interviews, and provides detailed information about the cause/effect relationships between system features and affect, but without interfering with the initial immersive experience.

4.5.1.2 Micro-phenomenological Interviews

During a micro-phenomenological interview (Bitbol and Petitmengin, 2016), a participant sits down in a quiet, comfortable environment with trained interviewer who guides them through the process of re-immersing themselves in an identified moment of interest from the experience, and discuss different aspects/dimensions of that moment. This method provides an in-depth access to rich information about the components and progression of an individual's experience.

We are combining these methods of qualitative inquiry, as cued-recall informs us about the VR system and environment, while microphenomenology allows us to understand the immersant's experience. For example, during cued-recall: *"Here, when I saw the lake I was tempted to go towards it, but the light seemed more urgent for me to follow, because I felt that the lake will still be there, but the light might not be"* P#1, Pr3 (an immersant reflects on the motivation for their trajectory in a particular moment supporting the design hypothesis of the Sprite being an affordance guiding through the narrative). Even though the cued-recall debrief is performed immediately after the experience, it might still be difficult for the immersant to access the experiential details of a specific moment from memory: *"And yeah, perhaps feeling something, feeling. . . I don't know. . . what was I feeling?. . . What was I feeling. . . I. . . "* – P#13, Pr3. To address this, the micro-phenomenological interview helps an interviewee to re-live parts of the experience, and describe the dimensions of it while re-experiencing it: *"That sense that you are weightless. Suddenly I wasn't conscious of my body pressing into the Earth. . . I don't know what was on the screen, or what I was looking at – it was all internalized. Which is kind of bizarre, now that I think about it"* P#2, Pr3.

We saw indications of the well-being effects of *AWE* during the second round of proto-typing. Immersants reported a sense of connectedness, and a calm attitude towards their problems when faced with the vastness of our world. *"I really liked it. I felt I was far away from reality, it felt really good. Especially when people are stressed out, they really need this, to calm down to think deeper. It's a mental health experience. I was thinking deep things, from the start, inside the lake and Universe... I was in a big environment thinking humans are really small."* – P#6, Pr2. The part about feeling small in the environment is particularly indicative of experiencing the feeling of awe (Shiota et al., 2007; Stellar et al., 2017).

4.5.2 Physiological Measures

In order to have an objective measure of the affective state of the immersant, we use phys-iological measures. It is important to correlate physiological measures with introspective measures to disambiguate the results.

4.5.2.1 Biosensors

In future user tests, we will use bio-sensors such as heart-rate variability, a breathing sensor, galvanic skin response (stress and affect), and electromyography (muscle tension) to get a precise measure of the moments of affect. We haven't used the sensors in the previous tests, as wearing multiple instruments and electrodes may significantly reduce the experience of emotion due to distraction and inability to move freely. Thus, it was important to first validate in principle if the installation could elicit an affective experience, and only then we can include bio-sensors to identify more specific moments of affect.

4.5.2.2 Goose bumps and Shivers

Goose bumps and shivers are an objective and specific marker of occurrences of awe (Panksepp, 1995; Benedek and Kaernbach, 2011). We use a purpose-built video camera and lighting setup to record forearm skin and determine whether goose bumps and shivers are present. For our initial pilot to validate the presence of goose bumps with reports of awe, immersants flew around the planet in VR. 43.8% of immersants experienced goose bumps, and those who had goose bumps had higher reports of awe (Quesnel and Riecke, 2017). The third *AWE* prototype, tested with 13 immersants, resulted in one occurrence of shivers/goose bumps during the climax, when the sun emerged alongside the Earth. More details of the physiological goose bump phenomenon and awe is in our forthcoming publication (Quesnel and Riecke, 2018).

4.5.3 Observational Measures

Researchers make observations on immersant behavior prior to, during, and after experiencing *AWE*. A frequent pattern is the increased calmness after the experience, inferred from speech and movement becoming smoother and slower. In future tests, we will collect observations on pro-social and pro-environmental behavior through staging a scenario to which the participant needs to respond.

4.5.4 Implicit Measures of Connectedness

To assess whether *AWE* increased the feeling of connectedness, we use an implicit attitude measure called the implicit association test (IAT) of connection with nature (Schultz et al., 2004). Three quarters of immersants in the third prototype phase showed a positive connection with nature after experiencing *AWE*.

4.6 Conclusion

The creation of *AWE* demonstrates advantages of the RBD process. When designing an installation with a goal of a specific profound emotion and psychological affect, it is imper-

ative to synergistically combine scientific and artistic practices. A scientific practice is often lacking the comprehensive understanding of what elicits emotional responses, which can be complemented by artistic intuition. Artistic practice can sometimes lack the grounding in scientific literature that can refine the goal of the work and motivate the design, but more importantly, the scientific practice contributes rigorous validation methods for assessing if the desired affect was achieved, and why. An important part of any design process (including RBD) that often gets neglected, is a thorough documentation. This is crucial because in such a long iterative process it's necessary to keep track of where ideas came from, so that design decisions can be formulated into a hypothesis and tested, and the outcomes of the studies are used to either validate these decisions or create new hypotheses. Researchers need to avoid accidentally using new evidence as the validation of a hypothesis that wasn't stated during the previous design stage, but only arose during testing.

Through the many iterations of *AWE*, we have progressively: (1) undertaken feasibility testing and refined understanding of the target emotions and corresponding validation methods; (2) identified system usability issues, (3) identified components of the system influencing affective response, (4) identified the importance of the the immersants' individual backgrounds and experiences and how to accommodate this as a design feature that can be personalized, i.e.: bio-responsive elements. With every iteration, new and more complex information became available to us. We have also learned how the setting where *AWE* is installed affects immersant experiences. Though lab studies provide the most controlled environment to collect data on the immersant's experience, testing prototypes at public events such as TEDx and local VR community meet-ups provided the most variety in demographics and behavior. Ultimately, we want to make the final installation in culture spaces, and as such we need to design for this setting as part of our next participatory design iteration.

AWE demonstrates how installations can be created that elicit profound emotional experiences, specifically awe. An artistic practice blended with research-based design practice in an RBD process results in a unique installation with transformative well-being potential, and a framework for future interactive installations to build upon.

> *"Everyone needs to experience this. Especially if they are going through a rough spot. . . I felt more connected to the universe, and that my problems were going to be OK, and going to work out somehow."* – P#19, Pr2.

Chapter 5

Understanding AWE

Can a virtual journey, inspired by the Overview Effect, lead to an increased sense of interconnectedness?

5.1 Abstract

Immersive technology, such as virtual reality, provides us with novel opportunities to create and explore affective experiences with a transformative potential mediated through awe. The profound emotion of awe, that is experienced in response to witnessing vastness and creates the need for accommodation that can lead to restructuring of one's worldview and an increased feeling of connectedness. An iconic example of the powers of awe is observed in astronauts who develop instant social consciousness and strong pro-environmental values in response to the overwhelming beauty of Earth observed from space. Here on Earth, awe can also be experienced in response to observing vast natural phenomenon or even sometimes in response to some forms of art, presenting vast beauty to its audience. Can virtual reality provide a new powerful tool for reliably inducing such experiences? What are some unique potentials of this emerging medium? This paper describes the evaluation of an immersive installation *"AWE"* – Awe-inspiring Wellness Environment. The results indicate that the experience of being in *"AWE"* can elicit some components of awe emotion and induce minor cognitive shifts in participant's worldview similar to the Overview Effect, while this experience also has its own attributes that might be unique to this specific medium. Comparing the results of this study to other virtual environments designed to elicit Overview Effect provides insights on the relationship between design features and participant's experience. The qualitative results highlight the importance of perceived safety, personal background and familiarity with the environment, and the induction of a small visceral fear reaction as a part of the emotional arc of the virtual journey – as some of the key contributers to the affective experience of the immersive installation. Even though the observed components of awe and a few indications of cognitive shift support the potential of Virtual Reality as a transformative medium, many more iterations of the design and

research tools are required before we can achieve and fully explore a profound awe-inspiring transformative experience mediated through immersive technologies.

5.2 Introduction

The overwhelmingly beautiful sight of our planet Earth triggers a profound emotional response in most astronauts and space-travelers, leading to a cognitive shift, making them realize the global interconnectedness of all life and feel responsibility for the future of our planet. This phenomenon was described by Frank White (2014) and termed the *Overview Effect.* This experience has the attributes of self-transcendence and awe (Yaden et al., 2016) and is a remarkable example of a transformative experience. Besides the Overview Effect, there are other experiences that have similar effect of evolving an individual as a changed person and promoting the feeling of unity or interconnectedness. For instance, such experiences happen in the context of interaction with nature (Tsaur et al., 2013; Williams and Harvey, 2001; McDonald et al., 2009) or in religious or spiritual context (Levin and Steele, 2005; Keltner and Haidt, 2003), as well as mystical experiences, meditation, peak and flow experiences during high task performance and several other contexts (Yaden et al., 2017a). The emotion of *awe* is often at the core of these experiences (Chirico and Yaden, 2018; Yaden et al., 2017a). Even though the terms 'transformative', 'transcedent' and 'awe-inspiring' experiences are not interchangeable, there is a large overlap between the phenomena they are describing. For the purpose of the project described in this paper, as we were aiming for the experience that is laying anywhere within the cluster of these phenomena, we will be discussing them together, without drawing a careful distinction between the terms.

Besides being an enjoyable and delightful experience (Shiota et al., 2011), such phenomena can have short and long-term positive outcomes: leading to increased well-being (Ihle et al., 2006; Suedfeld et al., 2012; Krause and Hayward, 2015), pro-social (Piff et al., 2015; Stellar et al., 2017, 2018; Prade and Saroglou, 2016; Yang et al., 2016) and pro-enviromental (White, 2014; Garan, 2015) attitudes, and even improved physical health (Stellar et al., 2015). The feeling of interconnectdness can lead to the development of social consciousness, which in turn would lead to prosocial behavior (Schlitz et al., 2010). However, despite all the benefits of transformative and awe-inspiring experiences, they remain rare, inaccessible to some people (e.g. due to physical or economic challenges) and could be challenging to achieve at will. Developing tools that could allow us to create environments that could reliably invite such experiences to happen would greatly benefit the world on both individual and societal levels. If we can facilitate the invitation of transformative experiences even only half of the time, that already would make such experiences much more accessible, and the tool allowing us to do that, arguably, would be able to claim itself as a transformative medium.

Virtual Reality (VR) technology with its controllability and ability to afford sense of presence could provide us with a unique medium to design for and study awe-inspiring experiences (Chirico et al., 2016), making them more accessible to the public and researchers (Stepanova et al., 2018b). The potential of immersive technology to create applications for positive change has been widely explored in different contexts, see reviews in Kitson et al. (2018a) and Riva et al. (2016a). A research group at the Università Cattolica del Sacro Cuore explored the potential of VR to induce awe in controlled lab conditions through using immersive videos (Chirico et al., 2017) and virtual environments (Chirico et al., 2018a), and were successfully able to elicit a self-reported awe response in some of their participants. Quesnel and Riecke (2018) and Gallagher et al. (2015) have also used virtual experiences of a spaceflight and evaluated its potential for inducing awe. Even though none of these studies observed a transformative experience of a similar scale to the Overview Effect in their participants, they still showed promising results indicating that VR, as a medium, could successfully provide immersive experiences that can trigger profound emotional responses such as awe.

However, there is still little research on the emotion of awe, as well as the phenomenon of the Overview Effect and other transformative experiences, that could inspire the design of a transformative experience in VR. Moreover, a larger body of knowledge needs to be build about the specific potential and affordances provided by VR for the design of profound experiences, as well as an understanding of what would someone's experience of going through such VR installation be like. As VR technology and affective design are both relatively new fields, it is important to not only bring in the understanding of how profound transformative experiences happen outside of VR as a guidance for the design of the immersive experiences and assessment of their effectiveness, but to also develop rich body of knowledge of how such immersive installations are experienced by different individuals. This study attempts to contribute to this developing body of knowledge by describing and analyzing personal experiences of individuals going through an immersive VR installation designed with a goal of awe elicitation and invitation of a transformative experience. This understanding will be essential for future assessment of VR technology as a more ecologically-valid approach to conducting controlled lab studies of complex phenomena and for informing design strategies, affordances and limitations for the development of profound positive immersive experiences with transformative potential. VR technology can not only allow us to 'replicate' in a virtual world experiences that are poorly accessible in real world, such as a spaceflight, but this medium also presents its own unique opportunities for creating spaces and journeys that can invite a transformative experience. For instance, technology in itself, with the vastness of the data it can connect you to, can elicit awe (Bai et al., 2017). Thus, it is reasonable to explore the virtual transformative experiences as its own subcluster of transformative phenomena with its own unique attributes and processes, but similar desired benefits such

as an increased feeling of interconnectedness, and the benefits for well-being and pro-social and pro-environmental attitudes that could follow from it.

In order to build this knowledge base about the transformative potential of VR and the phenomenology and attributes of individual's experience in a VR installation, we need to utilize our knowledge of profound transformative experiences to motivate the design of VR installations and then study the experience it induces as its own phenomenon. Using qualitative research methods allows us to develop an understanding of how personal experience is unfolding and what the important aspects of it are. Then, we can relate that understanding to the attributes of the design and the desired goal of the experience. Comparing the experience elicited by different VR installations would provide deeper insights in how different elements of the design of the experience, as well as the setting and participant's background might correlate with particular aspects of the elicited experience. Additionally, relating the personal experiences to the design decisions will help us validate our design hypotheses and intuitions, as well as propose new direction for further investigation.

For this study we designed an immersive VR installation *"AWE"* – Awe-inspiring Wellness Environment (Quesnel et al., 2018b) – that was inspired by the Overview Effect and other awe-inspiring experiences in nature. This installation is not an attempt of a virtual replication of an astronaut's experience, but rather an artistic creation aiming at eliciting an experience that will have some similar outcomes to the experience of the Overview Effect. In this study we discuss the aspects of the experience that the participants of *"AWE"* have described and relate their accounts to the research on the Overview Effect and awe-inspiring experiences. Firstly, we wanted to develop a better understanding of the different components of the experience of a person going through an affective VR installation like *"AWE"*. To achieve that, we performed in-depth qualitative interviews with participants about their experience. Secondly, we were evaluating whether the designed experience was able to achieve our desired goal of eliciting awe-inspiring experiences and ideally leading to a cognitive shift and increased interconnectedness. To do that, besides comparing the thematic analyses of interviews to existing qualitative research on awe and Overview Effect, we also implemented two quantitative measures that could be used for assessing components of the overview effect: occurrences of awe measured through goosebumps extending work of Quesnel and Riecke (2017) and Benedek and Kaernbach (2011) and connectedness to nature measured through an implicit association test (IAT) used in Schultz et al. (2004).

5.3   Material and Methods

5.3.1   Immersive experience and physical set-up

Participants were invited into the study room where there was a separate "tent" section for the virtual experience and the preparation area with a table and a laptop, where participants were signing the consent forms and doing the Implicit Association Test. The "tent" was set

Figure 5.1: A participant inside the tent(with the open entrance curtain) inside the *"AWE"* installation. The participant is seated on a swivel chair, wearing an HMD and noise-canceling headphones on his head, and a goosebump camera on his right hand

up with a 305 x 305 x 211 cm gazebo, that was diagonally separated with black curtains into the VR experience area and the researcher area (from where the equipment was operated). Inside the "tent" area there was an office chair covered with a blanket (to suggest the atmosphere of comfort) and some pillows on the floor to match the virtual environment; the outside of the "tent" was decorated with fairy lights, that resemble stars on the night sky when viewed from inside the tent, which corresponds to the first stage of the virtual environment (Figure 5.1). We have set up the virtual experience inside the physical tent for two main reasons. Firstly, we wanted to have an explicit entry into the experience space, that would separate it from the formal study procedures outside of the tent as different kind of space where a profound affective experience could happen. As such, the voluntary stepping into the tent was serving as a small ritual, that is proposed as a design guideline for transcendent VR experiences (Kitson et al., 2018b). Secondly, the tent was creating a semi-private environment where participants new that they were not being directly observed while they are going through the VR experience, and therefor they will be less likely to feel self-conscious about their behavior and can be more immersed in the experience. We

believed that these two conditions might be important for inviting the opportunity of a transformative experience.

Head Mounted Display (HMD) used in this study was an HTC Vive (2016 model, 2160x1200 total resolution, 1080x1200 per eye, 90 Hz refresh rate at 110 degree diagonal field of view). The navigation interface used for locomotion was adapted from Swivel Chair (Kitson et al., 2017), which uses the rotation and leaning of one's body for locomotion through a virtual space. Participants were sitting on an office chair and controlling their simulated self-motion by leaning in the direction they want to go, with the amount of leaning determining the translation velocity in the direction they were leaning. To rotate, participant will turn around on the chair that can spin full 360 degrees. Unlike reported in Kitson et al. (2017), the Swivel Chair in this study wasn't using any additional trackers and was calculating the position of the body based of the HMD's tracking. The interface was calibrated at the beginning of the experience for the individual participant's height.

The immersive experience *"AWE"* (Quesnel et al., 2018b) consisted of three environments: forest, lake and space. It was starting in a virtual tent in a campsite at night. A mystical creature "Sprite"(animated particle system) was inviting the immersant (participant) to follow it through the forest and make a jump of a rock into the lake, from where the Sprite was taking them through a portal to the outer space where in the climax of the experience the Sun and the Earth were revealing themselves. After orbiting around the Earth the experience was fading out and bringing the immersant back into the tent where it was now bright early morning (see Figure 5.2).

The three stages of virtual environment allowed for different amounts of active locomotion:

1. In the forest stage, immersants could freely explore the environment along the horizontal plane, with a limited ability to 'fly'(just a fraction of a meter) in the vertical axis before being pulled back to the ground;

2. when sinking through the lake, there is a limited range of movement in the horizontal plane, but the overall vertical direction is directed by descending within a virtual tube;

3. and in space they were taken on a pre-designed trajectory ('on rails') with a limited range of movement in all three axes.

A detailed description of the development of the *"AWE"* experience can be found in Quesnel et al. (2018b) (for a video of the latest prototype, see `http://ispace.iat.sfu.ca/project/awe/`).

5.3.2   Participants

Participants were recruited through a purposive sampling method with the help of our partner organization – NGX Interactive, a local Vancouver company that creates interactive
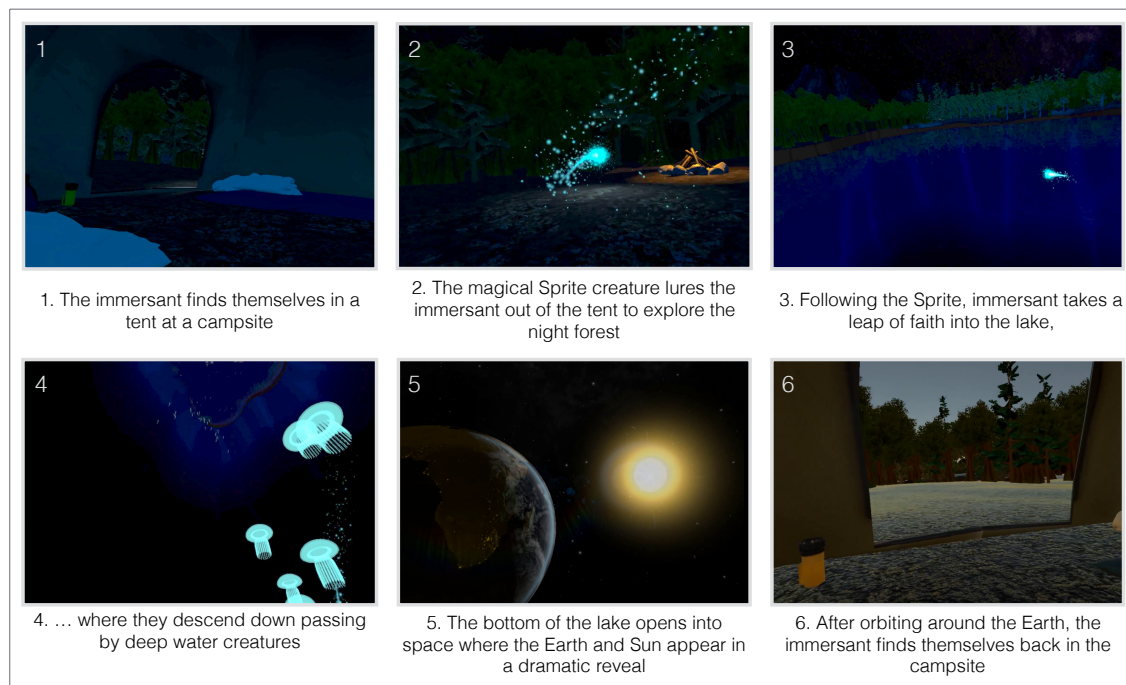
Figure 5.2: A summary of the virtual journey through *"AWE"*

exhibits for culture industry. Participants were recruited within the company's employees and clients, and as such are representing the community of professionals working in the field of culture industry and technology. We specifically wanted to recruit expert participants who will be able to provide us with well-informed feedback on the system and its potential to be used in culture industry for facilitating shift in worldviews, and who have experience with interactive technologies, and therefore will be more easily able to go beyond the initial 'wow' response, that first time users of VR sometimes experience. 15 participants took part in the study. When reporting the results, we will be referring to participants as P#. Two participants (P07,P15) were excluded from the data analyses as they did not finish the experience due to cybersickness, resulting in a final sample of 13 participants (7 females, 6 males). The ethics approval for the study was granted by Simon Fraser University Office of Research Ethics (Study#: 2017s0269).

5.3.3 Procedure

After being invited into the study room, participants were asked to read through and sign a consent form. Once they are ready, the participants were asked to enter the tent and sit down on the swivel chair. Then the researcher explained the set-up procedure and the navigation method and don the HMD and the noise-canceling headphones to the participant and assisted them with putting the equipment on, adjusting the fit if necessary. Participants were instructed in case of a mild cybersickness to close their eyes for a moment, and, if the feeling

persists or is strong, to notify the researcher and they would stop the experience. After the participant puts the HMD and headphones on, the researcher asked the participant to roll up their sleeve and put the goosebump camera (explained in the following section) on their arm. Once confirmed that the participant feels comfortable in the equipment, the second researcher starts the virtual experience, and the first researcher directs the participant through the initial calibration process for the navigation, while second researcher starts the recording of the streaming from the goosebump camera. After the calibration, the first researcher notifies the participant that everything is now in order and that they are going to leave the tent leaving the participant in privacy for the experience. After the virtual experience is finished, the first researcher returns back to the tent to assist the participant with taking off the equipment and sets up for either cued-recall or micro-phenomenological interview. After the interview, the participant is directed out of the tent to complete the Implicit Association Test (IAT) on a laptop. The participant's experience in the virtual environment was recorded through screen capture and the interviews were recorded with a Go Pro camera. The study took approximately one hour.

5.3.4   Evaluation Methods

5.3.4.1   Interviews

We collected the qualitative data through either cued-recall debrief (Bentley et al., 2005) or micro-phenomenological interview (Petitmengin et al., 2009) procedures. Both of these methods are designed to help participants to get re-immersed in the past experience and as a result to have more direct access to different aspects of the experience reducing recall errors and bias that could be introduced with the use of retrospective measures (Henry et al., 1994). We implemented both methods in order to assess how they fit into the context of research of affective VR experiences and compare them to evaluate what type of data they will be most effective at yielding. To minimize the recall errors caused by the delay between the experience and the interview, each type of the interview was administered immediately after the participant has finished their experience. To keep the study under an hour to avoid participant fatigue, we were only using one type of interview with each participant: four participants (P02, P03, P04, P09) were interviewed with micro-phenomenological method and nine with cued-recall debrief method. Each interview was followed by a short set of general questions about the experience. The type of the interview administered depended on the timeslot (determined by the availability of the trained micro-phenomenological interviewer), but, when signing up for the study, participants were not informed about the relationship between the timeslots and interview methods. Each interview took about 20-30 minutes.

5.3.4.1.1   Cued-recall debrief   After the experience was done, the first researcher would help the participant to take off the equipment, while the second researcher would turn

around the monitor and load the recording of participant's experience on the screen and set up the video camera for recording of the interview. During cued-recall debrief (Bentley et al., 2005) the participant would watch the screen capture of the experience together with the researcher and talk through what was happening at any particular moment of the experience. The researcher may prompt the participant with questions to direct their attention to different aspects of their experience, for example: *"What were you doing here?", "Did you have any thoughts when you looked up?"* or *"What did it feel like when you went in?"*; or to direct their attention to a specific behavior observed in the recording: *"You seem to be looking around a little more here, was there something that caught your eye?".*

5.3.4.1.2   Micro-phenomenology   Micro-phenomenological interview (Petitmengin et al., 2009) did not use visual prompts to assist the participant with re-immersion as in cued-recall, and was administered by an interviewer trained in the micro-phenomenological method. The interview started with a short practice interview not related to the virtual experience (but asking about a moment from the recent weekend) to give an opportunity for the participant to get familiarized with the method and what is expected from them in this type of interview. Then the interviewer asked the participant to identify one or a few moments in their experience that stood out to them and invited them to focus on each moment at a time. The interviewer than lead the participant through the process of the re-evocation of that moment directing their attention to different sensory and temporary dimensions of their experience.

5.3.4.2   Implicit Attitudes

We used the same Implicit Association Test (IAT) for assessing one's connection to Nature as reported in Schultz et al. (2004). This test asks participants to categorize words in one of the two categories by pressing "E" or "I" key on a computer with left and right index finger respectively. In the test trials the categories are appearing together creating either a congruent or non-congruent pair (Figure 5.3). The results are based on response reaction time and accuracy for congruent and non-congruent category pairs. The categories were Self vs. Other and Nature vs. Build with 7 blocks of trials. The test was administered on a 13-inch MacBook Pro laptop.

5.3.4.3   Piloerection

Piloerection observed in a form of goosebump or shivers can be used as a physiological marker of a transformative emotion of awe (Quesnel and Riecke, 2017; Benedek and Kaern-bach, 2011). A "goosebump camera" (See Figure 5.4) was placed on participant's arm to record a video of their skin throughout the experience. The researcher helped participant to put on the camera after the rest of equipment was already on and adjusted the focal distance from the camera to the skin for the best clarity of image. Video recording from the
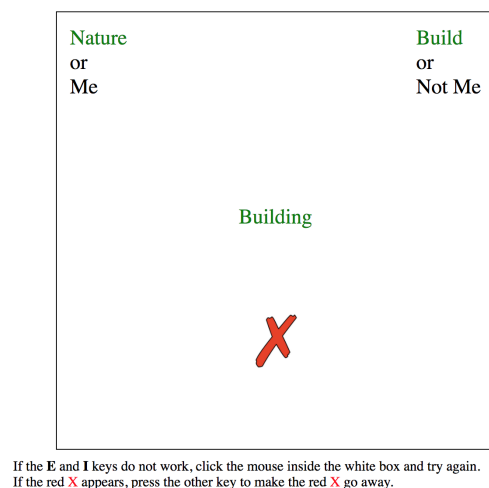
Figure 5.3: The Implicit Association Test (IAT) screen with congruent categories pairing and inaccurate response.

camera was manually synchronized with the screen recording of participant's experience for future alignment.

5.3.5   Analyses

5.3.5.1   Interview thematic analyses

The interviews were transcribed and imported into NVivo. First, two researchers independently went through all of the transcripts and identified meaning units and independently combined them into a higher level themes. The two researchers then compared and discussed the themes, they have identified, to agree upon one set of themes. Then the researcher went back to NVivo and proceeded with coding the transcripts. To minimize the researcher's bias in interpreting the data we used a bottom-up approach similar to interpretive phenomenology analyses (Smith and Osborn, 2004) and looked for themes that naturally emerge from the data instead of coding for the specific themes of interest. We will present the summary of the distribution of all themes, however, in the interest of space, we will only report in detail on the most prominent and relevant themes.

5.3.5.2   Implicit Association Test

We calculated IAT effect D scores of strength of association based on a standard algorithm for IAT (Wittenbrink and Schwarz, 2007). D scores have a possible range of -2 to +2. According to standard conventions we identified the strength of connection in accordance with the following break points: 'slight' - $(0.15 \leq |D| < 0.35)$, 'moderate' - $(0.35 \leq |D| < 0.65)$; and 'strong' - $(0.65 \leq |D|)$.

Figure 5.4: Custom made set-up of a wearable camera for recording a video of participant's skin for identifying goosebumps and shivers.

5.3.5.3 Goosebumps and Shivers

The video recordings from goosebumps camera were manually and independently coded by two researchers to identify moments of goosebumps or shivers. Moments of goosebumps are visually evident from hairs erecting, with the appearance of raised bumps on the skin. Shivers have less prominent raised bumps than goosebumps, but they are evident from micro-movements of muscles under the skin that visually look like a wave lifting the hairs up slightly.

5.4 Results and discussion

The first two section of the results report on quantitative data, and the following discuss the interview data. First, we present the interview data based on the thematic analyses of transcripts. After, we present the analyses of categories of emotions related to awe based on a hermeneutical analyses reported in Gallagher et al. (2015) and compare it to the results observed in Quesnel and Riecke (2018), that used Google Earth VR.

5.4.1 Implicit association test

Mean D score across all participants was 0.46 (SD = 0.54), which indicates a moderate strength of positive connection between Self and Nature. Nine participants had a moderate to strong positive connection (M = 0.78, SD = 0.23), two participants had slight or moderate

negative connection (M = -0.39, SD = 0.25), and two participants had neutral scores (M = -0.11, SD = 0.0015).

Comparing our result to D-scores obtained on the same IAT test by Schultz and Tabanico (2007), who observed an average 0.40 score between 60 undergraduate psychology students and 0.45 between 121 visitors to a park in California, we can speculate that possibly the effect of our virtual experience might have been similar to the effect of walking in the park in terms of one's implicit connection with nature. However, the sample sizes and the context in which the measures were conducted were widely different, and as such a strong comparison is not possible.

5.4.2   Shivers

In this study we observed one moment of shivers in one participant, when they were observing the sun revealing behind the dark (night) Earth. The Figure 5.5 illustrates the moment in the virtual experience, when the shivers occurred.
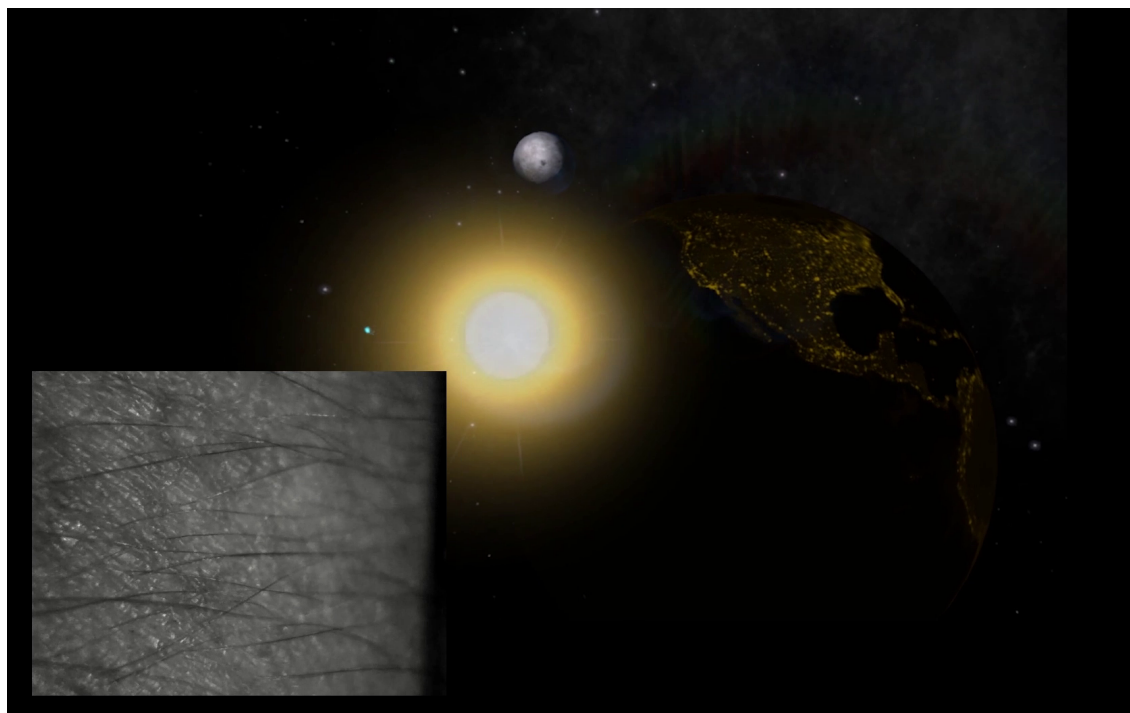
Figure 5.5: The moment of shivers: aligned recording from the goosebump camera and screen recording from the HMD showing the Earth scene with the sun appearing from behind it.

5.4.3   Thematic interview analyses

The Table 5.1 summarizes all the themes observed and coded in the data. For the purpose of this paper, we are setting the usability and design related comments aside, as they are

outside of the scope of this paper and will be reported in a different publication. We will be reporting on the most prominent and relevant themes to this paper, specifically: emotions and feelings, body-centric sensation and embodiment, familiarity and novelty (role of the personal background) and cognitive mini-shifts. This themes are highlighted in the Table 5.1 and their frequencies are summarized in Figure 5.6.
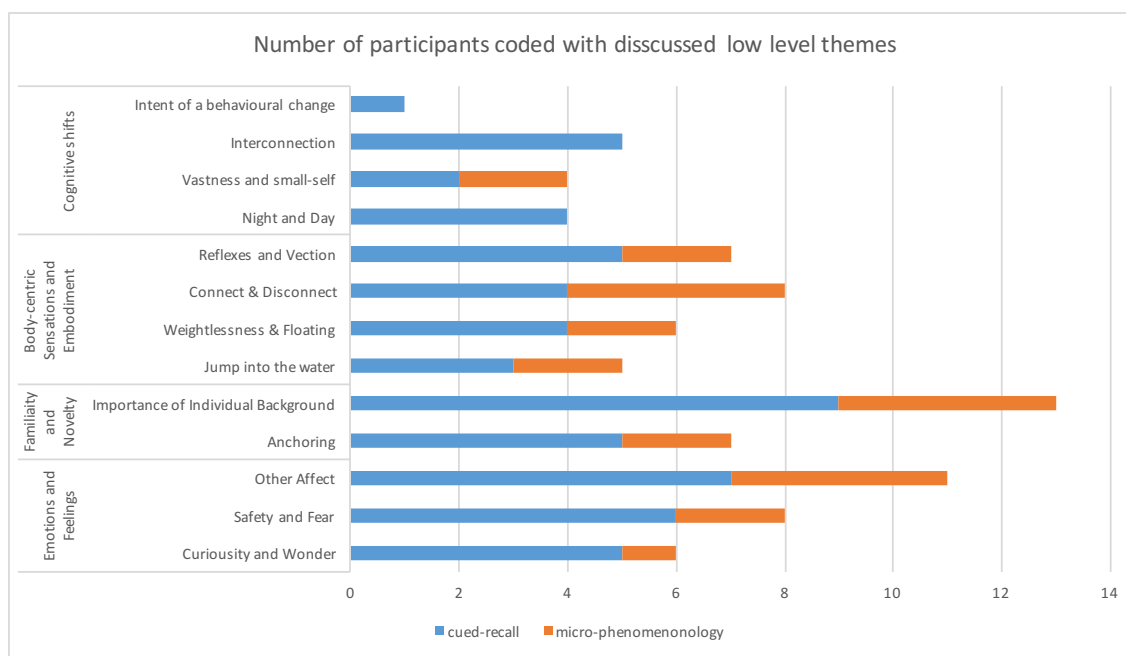
Figure 5.6: The number of participants (total = 13), that had statements coded with themes reported in this paper.

5.4.3.1 Emotions and feelings

5.4.3.1.1 Curiosity and Wonder After 'cool', 'interesting' and 'pretty', *'curiosity'* was the most frequent affect related word used by participants in the interviews. Curiosity and wonder were positive emotions driving participants' exploration behavior in the environment: "*Another sense of delight: Oh it's a lake! Not knowing what's gonna happen. Do I just look at the lake? But when I break through the lake its quite a sense of wonder: oh, that's quite lovely!*" (P08). The properties of the environment, specifically some level of mysteriousness or the 'unknown-ness' associated with it, were inspiring the curiosity: "*I was just curious about the environment. The environment felt deep. It reminded me the Truman show, where you have the bubble that you can explore.*" (P06), but at same time inducing some level of fear: "*It's really a lot of curiosity and I guess nervousness.*" (P11).

The novelty and new physical perspectives were also contributing to curiosity: "*I am enjoying the curiosity. I guess I was more interested in looking at the Earth, from this vantage point. I enjoyed looking at the space in reference to the Earth*" (P05).

5.4.3.1.2 Safety and Fear Most of participants (N=8) were distinguishing two states in relation to the environment: comfortable and safe vs. uncomfortable and scary.

Safety The majority (N=11) participants considered the first environment, the forest, and especially the tent to be safe and comforting: "*I thought the whole set up of the tent, and what I saw here... as a tent was really, like, I felt safe. I felt the tent provided a safe starting spot for me to start to going into the outside world.*" (P01). When aiming to achieve a transformative experience in VR, we believed that it was important to have a safe starting point, to help participants trust the system to take them on a potentially emotional journey and help them be more open to this experience. If the medium is not allowing participants to feel comfortable within it, they will likely be more resistant and closed-off from the experience. The physical and the virtual tent appeared to successfully serve that function for most participants. It was also important to conclude the experience with a safe environment. Here participant describes the last transition and coming back into the tent: " *this again is much more familiar, I do this every day kind of thing. It was comforting. Probably in a weird way one of the most comforting parts of it*" (P05). And since participants already developed some connection and familiarity with that environment, it was even more likely to elicit a sense of comfort: "*Cozy. I felt like I was home, even though it's a temporary home. Daylight, so it's more comforting*" (P06).

Fear Fear, was probably one of the strongest and most interesting emotional reactions we have observed in the data. Many participants reported to be a little 'scared', 'nervous', 'uncomfortable' or 'anxious', which was usually associated with the jump into or descend in the water, or in a few cases with walking through the dark forest. Both, the act of jumping of a height and the descend into the deep water was uncomfortable for some of the participants: "*Then I looked down and I see everything is dark, so for me it was .. I don't know how to explain.. it was just uncomfortable a little bit.. somewhere you are in the water and everything is dark and you are going down*" (P09). This was also the transition into the second stage where the locomotion was more restricted than in the first stage, which increased the level of fear induced:"*I know that if I jump into the lake I can get out as fast as I can, and it's up to me, but I felt like jumping in with the weights attached to your ankle – I am not in control of this situation and it doesn't make me feel comfortable. I am being lead. I don't want to be lead*" (P06). This also relates to the role of the sense of agency in the environment, the loss of which was often undermining participant's enjoyment of the experience.

There were a lot of strong bodily reactions to the jump and descend into the lake in the virtual environment, that was surprising and in some way profound for the participants:

> *I felt a shock. It felt like I was choked. That surprised me. It was not just like 'Oh that was kind of weird', I did feel like someone poked me or something. I*

felt an actual zap to myself, a tension, that I wasn't expecting. And not only that, the continued feeling, I was startled and was trying to recover from what continued for seconds beyond that, and disoriented: 'I don't know how I got here and I am not sure I like it here' – that kind of stuff that comes with a normal kind of shock. (P05)

The three strategies participants used to cope with this fear were: (1) dissociate yourself from the experience and bring yourself to the analytical level: "*Mentally overwrote back that this is just the experience.*" (P06), (2) find a comforting point of reference: "*There is fish, which is a comforting reference point in this black void. Trying to follow the light.*" (P05), and (3) just wait for it to pass: "*I noticed myself clutching my hands. I am not comfortable, I am just going to wait it out until it goes away*" (P06).

5.4.3.1.3 Other Affects   A distribution of both positive and negative valence affects were observed in the interview data. Negative affects were coming through two main sources: (1) usability issues were causing frustration and inability to explore something of interest was causing disappointment and (2) some parts of the environment were causing nervousness, anxiety or fear, which we will discuss in the sections below. Positive affects could be categorized into the following three groups: excitement, inner peace and appreciation of beauty.

Excitement   Participants were describing their experience as 'fun', 'exciting', 'wow'. These affects were often related to the visual and audio attributes of the environment: "*The sun was really exciting, because it is bright. There is music attached to it obviously, other than just my vision, it was also creating that kind of excitement. Bright and exciting*" (P04); or to an interest and anticipation: "*When I first looked around I was kind of hoping I would get to go in there, and when I saw that you can, there was a bit of excitement that I can go an explore the forest around. During that time I was actually looking around a lot. It was kind of immersive, it was fun*" (P03).

Another aspect of the experience that seemed to elicit excitement across a number of participants was the vertical dimension of the experience, which is opening a novel and interesting perspective. Often, when looking up: "*I am looking up. I kept looking up and thinking how far down am I. It was pretty neat, it was cool*" (P13) or down: "*So I didn't look down that much, but when I did, it was kind of fun and kind of scarier than looking elsewhere*" (P04) participants would describe themselves being more engaged and excited. While the lack of vertical dimension of gaze direction they considered to be the evidence of low engagement: "*I wasn't inclined to look up and down, I was looking more left and right, more like if you are in museum or something and you're kinda looking around*" (P03).

Inner peace   Participants were reporting feeling relaxed and peaceful. The soundtrack appeared to play an important role in it: "*It was very peaceful and soundtrack was nice and reminded me of nature and being in the forest*" (P08), which was also helping with coping with anxiety from jumping into the lake: "*The sound was calming, just seeing fish and seeing the opening above me made me feel a little more relaxed*" (P09).

Appreciation of beauty   Participants were describing the beauty of the elements of the experience and how it made them feel delighted or appreciative. Both, the mystical and novel environments like the nebula: "*There is something about it that I can't define. Because I know these are asteroids and that's probably a planet of some sort but then the fog is like 'Awww'.*" (P01) and familiar natural beauty of the forest: "*I like lakes, particularly because I can see the mountains and the sky behind it, so I wanted to look closer <. . . > I liked it, I can just sit there and look <. . . > in real life I would have just sat down on the rock and enjoyed the view*" (P06), as well as the beauty of the image of our planet: "*It's just visually really striking. And again, familiar because you've seen images like that. And, the contrast between the dark and the light is really nice. You can see the dark side still lit up with lights but the sun on the other side. It's really nice.*" (P12) – were all eliciting moments of appreciation and delight in participants.

5.4.3.2   Familiarity and Novelty

5.4.3.2.1   Relation to emotions   The feeling of safety or fear as well as curiosity and wonder seem to often be related to the feelings of familiarity and novelty. The first environment of a campsite in a forest was familiar to most participants, and associated with positive emotions, which let them feel comfortable going into the environment. "*It's a very familiar place. It's a tent, and there's a bonfire. There might be other people there. I chose to come here. I chose to be here and setup a tent and sleep in a tent*" (P01). Moreover, throughout the virtual experience, participants will form new connections with elements of the environment and use them to bring themselves back to the state of comfort in the parts of the experience that felt scary to them: "*. . . for my one comfort: 'here is the light, follow the light, here are some fish, I am being sort of acclimatized here' – that time helped*" (P05)

While usually familiar environments were providing a sense of comfort, for other participants, they appeared less engaging. Contrary, novel environments were stimulating curiosity, wonder and excitement. Here a participant is at the end of the lake scene: "*It felt like 'oh cool!' – Its not something you would normally be able to see, where is in the previous environment – I have gone camping before, so I get it. But here I am thinking this is cool, its really creative, really beautiful to see the stars through the water*"(P08). For some participants it was easier to accept and get immersed in more novel environments, they wouldn't have had a concept for, while having a compelling familiar environment seemed more challenging:

It is neat to explore a perspective on the world that you would have none of <. . .> Where is when anything that is too familiar, because I am so in-tune with how I walk and how that feels, so you have that disconnect <. . .> Where in space – I have no context for that. So okay, this is how I would float in space, fair enough, I have no other way of knowing it. (P02)

5.4.3.2.2 Anchoring The act of cognitive anchoring to a familiar place was quite prominent in the interviews, and it was not only used as a coping mechanism against anxiety and discomfort provoking environments, but also to orient oneself: "*I saw the sun and recognized it, and quickly after that I saw the Earth, so there was a relation there – I knew where I was for the first time in the experience. Not that I haven't been in a tent before, that was quite familiar. But there I for sure knew where I was.*" (P04) and to connect with the environment in a more meaningful way: "*This is kinda of an interesting angle of North America and South America. I have a colleague, who is working in Columbia right now, so I am trying . . . I am putting real people I know*" (P05).

5.4.3.2.3 Importance of individual variables and background We were surprised to observe quite a variety of polarly different responses from our participants within such a fairly simple experience, with a fairly consisted journey. Each of the stages and transitions in the experience has produced opposing responses from love to hate and from relaxation and peacefulness to excitement or fear. This distribution of reactions has stressed the significance of individual differences and background that participants are bringing into the experience.

The lake environment was the most striking example of opposing experiences participants were having in it and its relation to their background. One participant describes her delight in that stage: "*I just love the water, and so going into the water was quite delightful. Happiness, familiarity, for me not too calm, but connectedness to nature in that way, just being in the water, I love being in the water*" (P08). While another participant had a very different reaction to the same environment: "*A little worried. I don't like deep water. A little anxious. Okay, we got to go over to the lake, I hope we stay above it*" (P06). Transition into the lake as well, which was reported to be one of the most memorable moments by most participants, elicited opposing reaction depending on personal background: an uncomfortable anticipation and anxiety by one participant: "*coming down the little ledge to go in the water.. that was kind of .. I was a little bit hesitant before, because I don't normally like jumping into the water from height. Or jumping from height in general. < . . .> that feeling scares me a little bit*" (P09), while another participant had a positive anticipation and excitement coming up to that transitions "*Here I realized that okay, I am going down to the water, so perfect. This is great. < . . .> I was a little stoked, cause thats the direction where I wanted to go < . . .> I was a little bit timed here: Am I supposed to jump in here? < . . .> then I went for it*" (P11), this participant later mentioned that he is a cliff-jumper.

Another important influence on the experience was coming from the video games experience, that participants had, that was both helping them with navigation: "*I have a litle bit of a gaming background so I am sort of very comfortable with this first-person movement through virtual space*" (P13), and setting up an expectation to have a goal: " *it reminded me of old video games where there is like a mission or something, I wouldn't necessarily do that mission and I would end up going off somewhere else*" (P10).

5.4.3.3   Body-centric sensations and Embodiment

5.4.3.3.1   Jump into the water   As discussed in the section on safety and fear, the transition into the water environment, that was inviting participants to follow the light creature and jump of the rock into the lake, was inducing strong reactions in participants' bodies. They were describing clutching their hands, tensing up their muscles and holding their breath: "*all your muscles constrict, or contract, so it's almost like you are trying to hold yourself tight, so when you get that cold, you can release it once you hit the water*" (P02). This tension was often followed by a release and relaxation, when 'hitting the water': "*the body just kind of tense up, and you just kind of . . . just kind of muscles release . . . As soon as I got in the water*" (P09).

5.4.3.3.2   Weightlessness   Interestingly, that feeling of release might have facilitated the feeling of floating or weightlessness. Here a participant describes the moment when that release have happened:

> *That's weird, because, on the ground, up to that transition, I am super conscious of how I am sitting on a chair, and that kind of leaning forward is feeling a little awkward. . . But in that second I didn't feel the. . . And that's what I kind of loved too, is how, I had no idea you could reproduce that, give that sense that you are weightless, suddenly I wasn't conscious of my body pressing into the Earth.* (P02)

For a different participant a similar moment of release leading to the sense of weightlessness happened in the transition from the lake into the space: "*When I was in the water I felt like I was not in control and I was weighted down, like if I had weights around my ankles, where is when I was transitioning into the night sky it felt like the opposite: the weights are off the ankles, you are weightless*" (P06). This participant was afraid of the water environment, and even though that transition into space produced less internal bodily responses for most participants than the transition into water, the psychological release of letting go of the fear still lead this participant to experience the illusion of weightlessness.

It was interesting to observe that 6 participants have mentioned floating or the feeling of weightlessness in their interviews. It might not have been a strong bodily feeling for everyone, but it is encouraging to see that even with a simple hands-free leaning-based

interface through a design of the storyline and the visuals in a virtual experience, we were able to elicit some level of the feeling of weightlessness without submersing participants in a flotation tank (which would be a more literal induction of the feeling of weightlessness, for instance, planned by SpaceVR for 2018 Burning Man festival (Bonasio, 2018)).

5.4.3.3.3   Connect and Disconnect between mind and body   Imaginative immersion in combination with sensory immersion (Ermi and Mäyrä, 2005) when achieved successfully creates a condition in which participants experience a disconnect between their mind and body. Participants discuss these moments of disconnect, and having their perceptions overridden by their imagination as the optimal moments of their experience:

> *It was a bit more of the imagination and just like the feeling of being in warm water and submerging and yet not worrying about the panic of not being able to breath, and just something about that, that I quite liked. And maybe it's because I didn't feel this* [points at different parts of his body]*, right?* (P02).

While the moments, in which the conflict between the physical body position and the virtual position became apparent, lead to frustration and disappointment:

> *You start unpacking, okay, so you have this goggles, the audio here, and my arms and legs just feel static and crossed, how does that connect? Because that feels weird, when you come back to your body and then realize that it is a stagnate lump going through this* [points at where HMD would have been] (P02).

It would be interesting to investigate how this connect/disconnect transitions are being triggered. In case of this participant, he had this desired disconnect during the lake stage that was initiated by a visceral jump into the lake and then "*something broke the spell*" (P02) when transition into the space happened. For him, the transition into the space came as a surprise and did not make sense. For a different participant, the conflict was the result of not having an avatar representation in the virtual environment:"*I felt a bit disconnected from my body, because when I look down I don't see my body, and usually its there, obviously*" (P04).

5.4.3.3.4   Reflexes and Vection   Vection (an illusion of self-motion) and reflexes are often perceived as an indicator of how immersive and 'believable' the experience was by participants.

For example, a participant describes descending down in the lake: "*I see the sparkles, < . . . > I realized that they are kind of like surrounding me, that's when I really got the sense of the descent down. The closest I can compare it to is when you are going down a roller coaster, but it wasn't that intense, it was more calm kind of feeling*" (P03) and then going into space: "*As soon as the movement started, it kind of again felt a bit more immersive, the*

floating feeling came back again" (P03). The lack of self-motion illusion for some participants in the third stage of the VR experience combined with restricted locomotion might have also contributed to some of them feeling as if they are watching a movie instead of participating.

At moments, participants would also report having a reflex in reaction to an event in the virtual environment: for example, when the sun appeared, a participant was surprised and reported:"*I am pretty sure I jumped.*" (P05) while another participant: "*I found the sun pretty bright, almost wanted to put my hand up. But yeah, this is neat.*" (P10). While putting the hand up to protect one's eyes wouldn't have worked in a scenario of wearing an HMD, a different participant adopted her reflexes from diving to the VR equipment: "*because I'm a diver I felt like I'm descending, there was one point were I adjusted my face but it's a bit like adjusting your regulator.*" (P14). This type of behavior could potentially indicate how 'real' the experience was for the participants at that moment.

This 'realness' and 'being there' of the experience, that is indicated by multidimensional responses, including your internal body feelings and actions, are likely an important precursor to the possibility of transformative experience that could lead to cognitive shifts. For instance 'presence', which is often described as the feeling of 'realness' or 'being there' in a virtual experience was shown to correlate with a stronger effect of the virtual experience on the following real world behavior (Fox et al., 2009; Rosenberg et al., 2013).

5.4.3.4   Cognitive mini-shifts

As the ultimate goal of this project is to evaluate if VR experiences can be designed to elicit positive cognitive shifts in the immersants similar to the Overview Effect and other awe-inspiring transformative experiences, we were excited (and a little surprised) to see some indication of some minor cognitive shifts voluntarily described by participants in the interviews. Participants themselves were also intrigued by the shift in perspective resulted from their experience, even when the shift was in the perception of seemingly simple concepts:

> *I kinda compared that sort of spatial environment that I was in with all of the representations of space that we get used to, which is a very 2D item, the solar system prospective. And that difference, that being in it, and that way how it altered my sense of that relational space of one celestial body to another, that was really cool actually how it changed something in my mind slightly.* (P13)

5.4.3.4.1   Day and Night   Four participants found the concept of day and night happening at the same time on different sides of the globe, that was observable in the experience when traveling around the Earth, very interesting. Even though they are intellectually familiar with this idea, seeing it from the first person perspective was to an extent an 'eye-opening' experience. Participant reflects on her mental process of coming to that realization:

To realize that it is so easy to look at something through one lens, but when, if you are exposed to it in a different way, then something that was so familiar to you, we thought it was just the way it is, can look so different and give you such a different perspective. Something as simple as that sun is not shinning on the other side of the half of the world, means its night time, and it's so simple. And I studied, moons, and tides and sunrises and sunsets, but never thought about it quite so simply: that sun is shining on one side but not the other side. (P08)

5.4.3.4.2 Vastness Vastness can be better described as part of the perceptual experience that could lead to a cognitive shift (rather than a shift in itself), but as it is considered to be the precursor for the experience of awe (Keltner and Haidt, 2003) and cognitive shift of perspective (Gaggioli, 2016), they are closely related. A participant, who works at an aquarium described:

I remember thinking that the Pacific ocean is so big and for a while I thought that I am not seeing things correctly. Which is funny, because I < . . . > know that its huge. But it was so vast! And to see it in that perspective was what was very unique for me. < . . . > It was impressive and gave me another perspective on something that I see and think about everyday. (P04)

This admiration of vastness is also often related to the realization of how small each individual human is on the scale of the whole world. Here a participant describes his thoughts when orbiting around Earth: "*I was really hoping to see maybe that sparkle of the civilization, some kind of movement, some kind of glimmer, to denote my . . . what's the word . . . like the size of people, how small compare to where I am*" (P03).

5.4.3.4.3 Interconnection Overview effect and other transcendent and awe-inspiring experiences have all in common the cognitive shift leading to a realization of interconnectedness of life. In our data there were a number of instances that could indicate this realization of wholeness of the world:"*transition from the bottom of the water into the space scape and that sort of the initial moment when you look at it holistically and you see . . . everything is involved in it*" (P11). But the most striking was the observation of the participant when traveling around the Earth:

There has been so many natural disasters lately with the hurricanes, fires and all of that.. When you see at a global level, the connection between things that are otherwise separate because of the political things... When you see as a whole – its just like, well, its just one planet. When you go around and see that Brazil is so close to Florida, you know politically things are so far away... (P06)

This realization of interconnectedness can then lead to behavioral changes, where in case of the Overview effect, astronauts feel the need for everyone to unite together to protect our planet and the people and animals living on it (White, 2014).

5.4.3.4.4 Intent of a behavioral change In our data there were two comments from one participant that could suggest an intent for a change in behavior, that could be triggered by the feeling of interconnectedness. Firstly, on a personal level, she was inspired to learn more about other people and countries she may not know enough about: "*I liked that, because I don't know much about south America, so it was interesting to look at it when I can see all other distracting places I know more about. I thought I should learn more about it*" (P06). This could be related to the aspect of perspective shift related to brining cultures together by developing an understanding of other cultures (similarly to what astronauts describe (Gallagher et al., 2015)). Secondly, on a more global level, she also had the urge to communicate this view of interconnectedness to more people:

> *Just need for people to figure out the environmental sciences, because its effecting everybody, but these are the artificial lines that seemed to be so unhelpful. I was thinking from the educators perspective. What a disservice it is to see a map as flat: things look so much further apart than they actually are. And that need – if we are going to problem solve bigger things, how this flat political map is just not going to get us there.* (P06)

5.4.4 Gallagher's Hermeneutic analyses of awe

Gallagher et al. (2015) undertook syntactical followed by hermeneutic analysis of astronauts' awe experiences based on 51 texts authored by 45 astronauts and cosmonauts. From the analysis, Gallagher *et al.*, generated 34 consensus categories of awe. The categories are valuable, because researchers can use them to determine whether in experimental studies, participants have experience of awe and consequently the Overview Effect can be replicated outside of actual Outer Space. Here, see Figure 5.7, we count the frequency of statements made by our participants that fit into the awe consensus categories. The categories that were not observed in our data and not included in the graph are: sublime, poetic expression, peace (conceptual thought about), inspired, home (feeling of being at home), fulfillment, floating in void (not related to weightlessness), elation, disorientation.

We can compare the results of this study to the study by Quesnel and Riecke (2018), that had 16 participants traveling through Google Earth VR, whose interviews were coded with the same categories of awe based on Gallagher et al. (2015). Figure 5.8 shows the comparison of the frequencies of participants coded with the awe consensus categories between these two studies. The *"AWE"* experience was able to elicit more responses of totality, spatial perspective shifts, sensation of floating and inquisitiveness, while the Google Earth
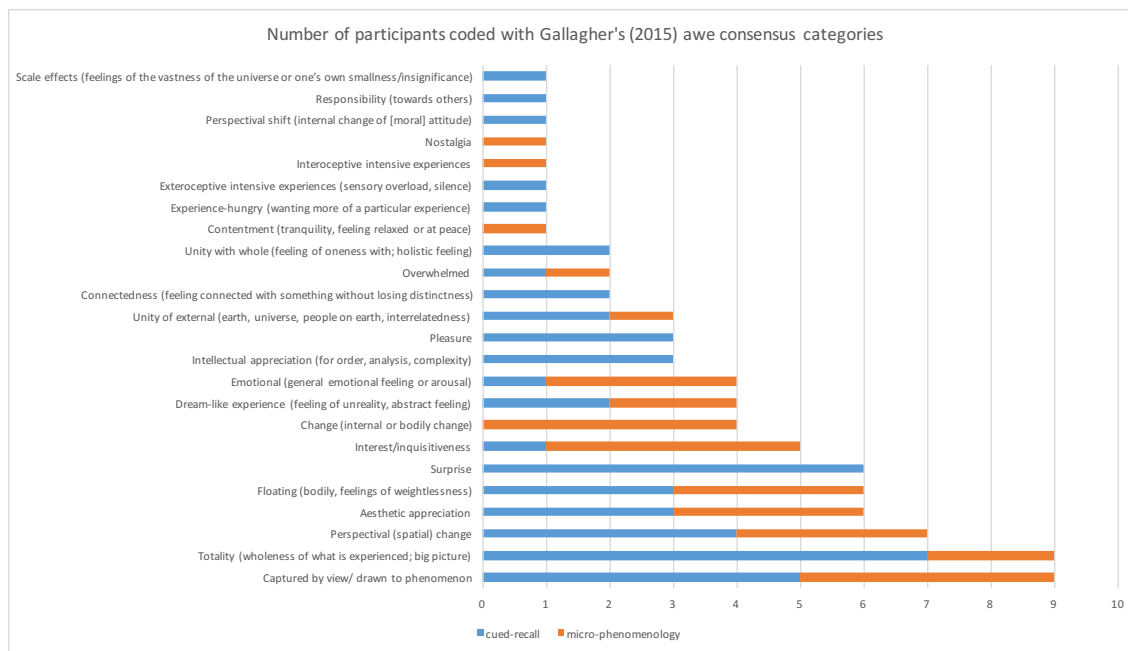
Figure 5.7: The number of participants, that had statements coded with hermeneutics analyses of categories of awe (Gallagher et al., 2015).

experience was better at eliciting feelings of sublime and elation. We can speculate that the sensation of floating and inquisitiveness were elicited as a result of the narrative arc of the *"AWE"* experience, that wasn't a part of the Google Earth experience used in Quesnel and Riecke (2018). Totality and the spatial perspective shifts observed in our data a likely related to the *"AWE"* experience presenting the Earth from a more distant perspective than Google Earth VR allows. While the lack of sublime and elation responses in our study could be explained by the difference of the quality of the Earth models that we had in *"AWE"* and in the Google Earth VR.

Gallagher et al. (2015) in their studies did not report on the number of participants coded with a certain theme, but rather the total frequencies of codes (within 19 interviews). However, since the lengths and types of interview procedures were different between the current and Gallagher et al. (2015) studies, we can not make a precise comparison based on these counts. Still, in their data the most frequent categories were perspective shift (moral,internal), contentment, interest/inquisitiveness, scale effect, and significant sensory experiences, which only partially intersects with our data, as these categories, even though present, were not as prominent in our data. The study design was fairly different between our studies: Gallagher et al. (2015) study used a spaceflight simulation, designed to be realistic, that was presented through the screens of cockpit/windows in a study space as opposed to an HMD. As their study was a more literal simulation of a spaceflight than *"AWE"*, it is possible that their participants were more inclined to think about what they

know about spaceflights and astronauts' experiences, so it is possible that some of these thoughts were introduced externally based on associations rather than emerged from the properties of the experience.
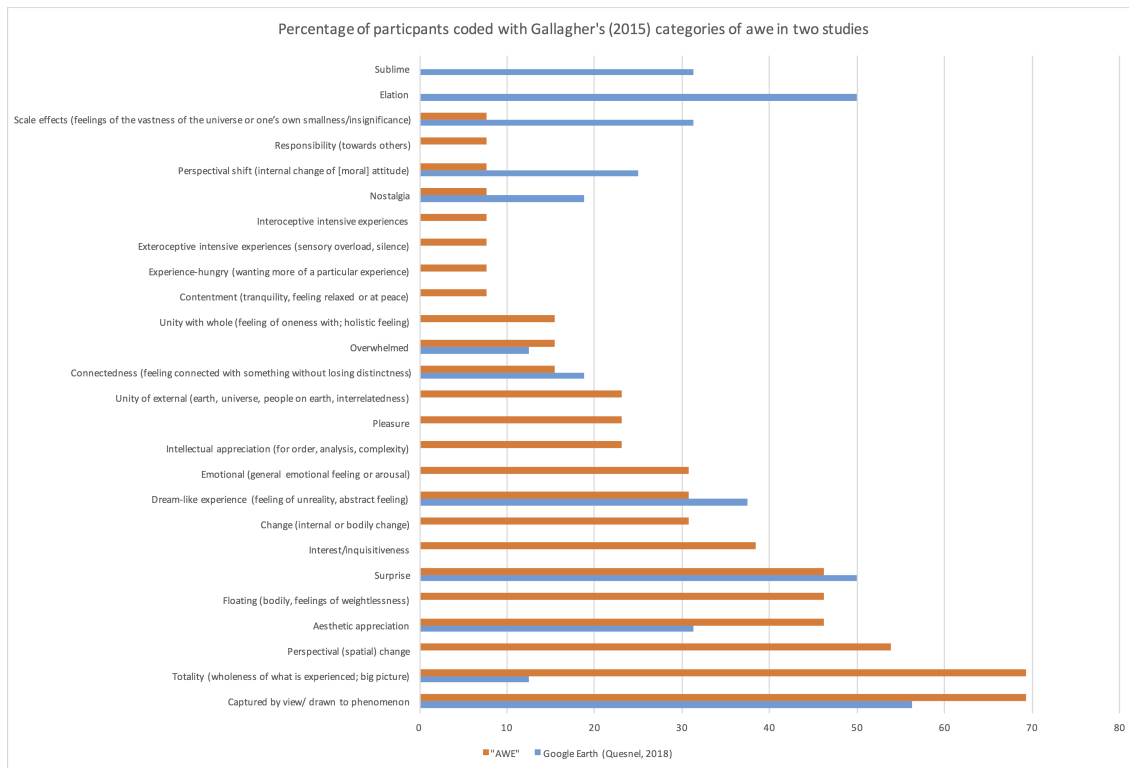
Figure 5.8: The percentage of participants, that had statements coded with hermeneutics analyses of categories of awe (Gallagher et al., 2015) in current study and Quesnel and Riecke (2018).

5.5 General Discussion and Limitations

5.5.1 Relating to the Overview Effect

Stepanova et al. (2018a) analyzed existing records and research on the phenomenon of the Overview Effect and derived design guidelines and evaluation methods for virtual experiences aiming to elicit the Overview Effect or an extent of it. By comparing the themes that emerged from our interview data and the guidelines outlined in Stepanova et al. (2018a), we identify an intersection in the following themes:

1. From Design Guidelines

    (a) Embodied Experience and Self-relevance

    The feeling of being in the virtual environment and having a first-person experience of it

(as opposed to watching a movie), that can be facilitated though a full-body experience and a perception of being an agent in the environment

(b) Privacy and Social Space

A combination of a private physical space, where the virtual experience is experienced, to facilitate immersant's comfort and openness to the experience, and a social space following the virtual experience to facilitate the process of accommodation

(c) Vastness

Creating virtual stimuli that can facilitate the experience of something that is much greater than oneself

(d) Suspending disbelief through aesthetics.

Using imagination-provoking imagery to assist the suspension of disbelief and openness to experience

(e) Initial fear

Including a fear-inducing part at the beginning of the emotional journey to imitate the emotional trajectory that astronauts go through when being shot in a rocket into space

(f) Weightlessness

Facilitating sense of floating or weightlessness to imitate zero gravity environment

(g) Personal Connection

Providing familiar elements into the environment to help immersants establish personal connection with them, that then can be extrapolated into a larger feeling of global interconnectedness

2. From Evaluation Guidelines

(a) Weightlessness

Feeling of weightlessness or floating

(b) Changed perception of space

Altered perception of the relative size, distances and positions of celestial objects and geographic locations as well as the relative position of oneself in relation to them

(c) Awe

Emotion of awe that can be evident from introspective, physiological or implicit measures

(d) Interconnectedness

The feeling of or a realization of global interconnectedness of all people, living species, or the planet at large. Transcendence of one's perceived boundaries of self and the feeling of belonging to something greater

(e) Increased Responsibility for Earth

The concern for and desire to protect the environment and all of the inhabitants of our Earth

From the evaluation guidelines we were pleased to observe a number of mini-shifts reported by participants, that would indicate each one of the 2b-2e themes. Even though we only observed a few instances of each of these shifts, it was still very inspiring, considering that cognitive shifts are not easy to achieve, and it was still an early prototype of *"AWE"*, that requires more design iterations.

From the design guidelines, the most strong and interesting intersection was in the privacy, initial fear, weightlessness and personal connection components.

Privacy and Social Space: Even though participants were not using the term 'private' when describing their experience, from their discussion of felt safety and comfort we can speculate that *"AWE"* was able to achieve the goal set out by the 'privacy' design guideline – creating a safe space for participants to feel comfortable to have a transformative experience. The social space guideline was aiming to assist with the process of accommodation that is a necessary component of a transformative experience following a witnessing of an awe-inspiring phenomenon. Even though only one participant explicitly discussed it at the end of his interview, but he reflected on how going through the process of the interview was valuable to help him unpack his experience and understand it on a deeper level than if he was just asked a few questions about it. As such, we believe that the interviews, especially the microphenomenological method, were able to provide the social space and the conversation that could facilitate the process of accommodation if a participant has a transformative experience.

Initial Fear: The precursors for the Overview Effect, in its traditional description, are hard to separate from components of a spaceflight, but the initial moment of fear that astronauts naturally have from being shot in a rocket into space, is, quite possibly, an important stage in the progression of the experience (White, 2014). However, few people have personal experiences associated with rockets, and as such, jumping into water is a more visceral experience for most and therefore, when part of VR, has a potential to induce stronger response in immersants, which we indeed observed in our data. However, we were surprised by the strength, length and frequency of fear experiences of our participants, as we were only intending for the jump into the lake to be a moment inducing some fear and requiring participants to take the leap of faith. The personal background of participants shaped their experience of descending through water to be more fearful than we anticipated in the development of *"AWE"*.

Weightlessness: The feeling of weightlessness also has an unknown connection to the Overview Effect because the personal records of them are inseparable: it might be essential or not relevant (White, 2014). As the sense of weightlessness on Earth is logistically challenging to achieve in combination with a virtual experience, we were not aiming to replicate it as a part of the experience. It was insightful to observe in the interviews that several participants did have a feeling of floating or weightlessness, and informed us how the narrative of the experience can facilitate the induction of this sensation.

Personal Connection: From the account of the Overview Effect it appears that, at least in some cases, the feeling of connectedness starts small from the personal connection to a familiar location, and then extends from there to the rest of the world. It was interesting to see in our data how prominent the concept of familiarity was – 10 out of 13 participants were discussing it (with no targeted prompts from interviewers). Two participants also described how, when orbiting around the Earth, they were picking out familiar locations to establish connection to them, much like the astronauts describe looking for, for example, Houston when earthgazing. The virtual travel to a familiar place in Google Earth was also powerful at eliciting awe in participants of the study by Quesnel and Riecke (2018).

The other three design guidelines (embodied experience and self-relevancy, vastness, suspending disbelief through aesthetics) were not as evident in our interview data. Even though there are some indications of **self-relevancy**, for a lot of participants it was significantly reduced as a result of restricted paths of locomotion in the second and third part of the experience. While perceived **vastness** was mentioned by three participants, this is a fairly low frequency for an experience that is aiming to elicit awe (Keltner and Haidt, 2003). **Suspending disbelief through aesthetics** was only partially successful, as there were a lot of participants who were still expecting an accurate representation of the real world inside the virtual environment and were thrown off by any observable conflicts. Despite the clearly magical creature of sprite and the lake portal into the space some participant's sense of immersion was broken by seeing jelly fish in the fresh water, some trees appearing too tropical for the local biosphere or that the tent seemed to be too large for one person. Evidently having magical elements in the narrative wasn't enough for fully suspending participant's disbelief, especially when they were very familiar with a specific environment (e.g. the jelly fish comment was from a participant who works at the aquarium). It might be important to set up the right expectations from before the VR experience starts by adding a narrative to why participants enter the tent for going into the VR experience to prepare them for the virtual story, that is not meant to follow all the rules of our reality perfectly.

Overall, even though the *"AWE"* experience did not closely follow all of the guidelines outlined in Stepanova et al. (2018a) for the design of the virtual experience of the overview effect, it was able to achieve some indications of each one of the core components of the overview effect: awe, increased connectedness, increased responsibility for the environment. The latter being indicated only once through one comment by a participant discussing the need for everyone to unite together to develop a better understanding of the weather systems as it is effecting everyone. While *awe* is fairly complex emotion, it is hard to make definite claims as to how much awe did our participants experience: their interviews indicate a number of components of awe identified by Gallagher et al. (2015) specifically in the context of the overview effect. However, the physiological measure of piloerection (Benedek and Kaernbach, 2011; Quesnel and Riecke, 2017) revealed only one instance of awe in this study, which is either the fault of the recording instrument or, more likely, the result of

the lack of intensity of awe that, even though experienced to some degree (evident from interviews), didn't trigger the physiological reaction.

Connectedness is also a difficult cognitive construct to objectively measure, that we attempted to do with IAT. IAT scores indicated a fairly strong connection between Self and Nature, however these results are still challenging to interpret, as we don't have a baseline for our population of professionals of interactive technologies in Vancouver, Canada. We made the comparison with the data collected with the same IAT test (with identical categories and word items) in California, which could be considered an approximately comparable population as they are both located on the West Coast of North America, although there still might be differences between these populations. Besides not knowing the baseline for our population, we also cannot know how much of the connectedness of nature and self was attributed to the *"AWE"*, and how much of it was a personal trait of the participant, so the results either reflect the general state of connectedness with nature of the participants, or the effect of the virtual experience. Implementing IAT as a pre- and post-test measure could be a possible approach to tackling this challenge (as for example was done by Peck et al. (2013) in the context of racial bias), but as a reaction time based measure, IAT scores are greatly influenced by learning effects, and as such, repeated test become difficult to interpret as a measure of change and not a measure of test-retest reliability. IAT is very rarely implemented as a pre- and post- measure, and as in the study by Peck et al. (2013) it requires inviting participants to come to the lab multiple times, and even then still expects to observe a strong learning effect. The qualitative data in our study, however, showed some promising indications of moments in participant's experience of realization of interconnectedness.

As traditionally the records of the overview effect are describing a moment during the spaceflight experience, it is difficult to separate which components of a spaceflight experience might be contributing to the overview effect and which ones are unrelated, so until this relationship is clarified, we will have to target both the components of the spaceflight experience and the overview effect experience in our VR experience design. In our data we observed some indications of some components of an experience of a spaceflight: change in perception of space and weightlessness, but not the change of perception of time and silence. However, we did not specifically try to measure them.

5.5.2   Comparing to other VR awe-inspiring experiences

Chirico et al. (2017), Chirico et al. (2018a) and Chirico et al. (2018b) have shown that an immersive experience of awe-inducing stimuli were associated with a self-reported awe measured with a questionnaire, however these studies used less interactive environment than in our study, and did not perform an extensive qualitative analyses of how a participant's experience in VR unfolded, what some key components of it were, and how they relate to aspects of the environments used for the studies. Our study is most similar to Gallagher et al. (2015)

and Quesnel and Riecke (2018), who also used a VR experience of a spaceflight/orbiting the Earth and collected qualitative interview data. They reported participants' experiences of awe in those virtual environments across 34 consensus categories defined by Gallagher et al. (2015) hermeneutic analysis, and compared participants' reports of the virtual experience to real-life accounts from astronauts, with some similarities identified. However, the environments used in both of these studies were aiming to provide a realistic representation of the view of the Earth from outer space, and did not have a strong narrative component unlike *"AWE"*. Conversely, with *"AWE"* we were not aiming to provide a direct, realistic representation of the astronauts' actual experience in outer space, but rather wanted to integrate specific design features (artistic strategies and narratives) to create a target emotional journey in a research prototype, not a finished commercial product. Our installation has elicited less observable goosebumps than Google Earth used in Quesnel and Riecke (2018), which could be due to a lower-fidelity quality of the Earth model and usability issues in *"AWE"*. Another reason might be that in Quesnel and Riecke (2018) participants had a choice of their destination in Google Earth and would often travel to their hometown, which was eliciting nostalgia, which could have contributed to awe. Another explanations might include limitations in the wearable goosebump recording instrument, which changed in prototype design from Quesnel and Riecke (2018) to the present study; see section on Limitations below. However, it should be noted that hermeneutic analyses of interviews have produced comparable distributions of reports related to awe categories between current and Quesnel and Riecke (2018) studies, meaning that while goosebump recording may have failed to detect physical indications of awe, the qualitative analysis has shown some reliability. The observed differences in distribution of awe categories can be explained through specifics of the design of the experience, as discussed above.

Even though our *"AWE"* installation in its current state did not elicit profound transformative experience in participants of this study, it showed promising results supporting the premise that VR installations can elicit authentic emotional experiences and induce minor cognitive shifts in some participants. This study has also revealed some important aspects of an experience participants have when experiencing this type of an immersive installation: specifically the safety and fear of the environment, familiarity and novelty, affects and bodily sensations were prominent themes for participants reflecting on their experience.

5.5.3 Key outcomes

The elicited fear and the relief from it were an especially interesting part of the experience of many participants. Astronauts also describe a similar transition including the association of the release from fear with the feeling of weightlessness and silence experiences when floating in space (Stepanova et al., 2018a). This suggests an intriguing opportunity that a narrative in VR affords: where we could replicate some part of an emotional journey associated with a spaceflight with a use of a different and more familiar and visceral metaphor. If we have

had recreated in VR an actual spaceflight experience, that probably wouldn't have achieved the same intensity of an emotional response as a jump into the lake did. This could also be indicated by an observation that for most participants the lake or the forest were the environments they felt the most emotionally connected to. However, when designing a VR experience seeking a profound emotional reaction, we should be careful with inducing fear to ensure that we don't create a traumatic experience (Madary and Metzinger, 2016). It's important to learn from the variety of the experiences that participants had and to design the virtual journey in a way that focuses on facilitating the relief after the minimal induction of fear.

To the best of our knowledge the role of psychological relief on inducing the feeling/illusion of physical weightlessness hasn't been discussed in the context of VR experience design. However some VR experience were able to induce the feeling of floating or weightlessness. For instance, a meditation walk through a virtual forest for chronic pain management was able to elicit the sensation of weightlessness at least in one participant of Tong et al. (2016). Their study doesn't report on what might have triggered that sensation, but it is possible that it was a similar mechanism of *relief/release*, but in their case from some of the participant's chronic pain. Jain et al. (2016) discussed that some of the divers participating in their virtual scuba-diving simulation felt weightless. However, it's hard to determine what have triggered it: it might have been that the familiarity of the environment brought back participants' memories of past diving experiences, or that the physical set-up of the simulation that was involving a swiveling torso support and harnesses for the limbs was responsible for the sensation, as participants were more or less suspended in the air. These type of set-ups dedicated to specific floating experiences are arguably a little cumbersome and expensive, as they often include large physical structure, moving platforms or strapping participants into harnesses, for instance: flying interface such as Birdly (Rheiner, 2014), skydiving (Eidenberger and Mossel, 2015) or swimming (Fels et al., 2005). Even though these interfaces often provide very compelling experiences, some easier and cost effective solutions are desirable. Learning from the reports of our participant's describing the moments when they suddenly felt weightless could provide new strategies for developing VR experiences inducing the feeling of floating and weightlessness without the need for complicated physical set-ups.

The number of fear responses observed in the interviews stressed the high importance of understanding the personal background of participants, and that each individual's experience would be very different. Experience with video-games tend to help with objective performance measures in VR simulations, e.g. in a surgical simulation (Grantcharov et al., 2003). Based on our observations, gaming experience has not only influenced how quickly participants were able to learn the navigation interface and efficiently navigate through environment, but it also significantly shaped what expectations participants brought in. We propose (and explore in our ongoing studies) for affective VR installations to design a

pre-VR environment to help create appropriate expectations of the VR experience being an experiential piece as opposed to a game that is presenting a challenge that a gamer participant often begins to seek when entering a 3D environment. Also, the individual experiences with forest and water environments were key for how their virtual experience unveiled. Some of our participants had diving, cliff-jumping and camping experiences, while others also reported getting lost in the dark forest in childhood or being afraid of jumping from heights. All of them formed a connection between their personal experiences and being in the virtual environment, which greatly effected their experience. Given everyone's different backgrounds at the design stage it was difficult to predict the distribution of the reactions of participants. Similarly, Shin (2018) in his study showed that personal traits and predispositions of immersants may have a larger effect on individual's experience of an empathy-provoking VR (specifically level of embodiment and empathy elicited), than the specifics of the VR experience and interface. Including interviews and demographic surveys, as well as pilot tests with varied demographics should be an integral part of the development of affective immersive installations in order to be able to understand participant's experiences, and what was the contribution of the installation to the affective state achieved by the participant. Studies of complex experiences and emotions that only collect quantitative data face a risk of not having the tools to disambiguate the responses they observe that stem from different participants backgrounds and mis-attribute it to the components of the virtual system. This also raises the issue of whether 'one size fits all approach' could be suitable for immersive affective installations. It will be interesting to explore if procedural content generation in combination with bio-responsive environments can help create a more customized journey for each participant building on their personal background and reactions to the elements of the environment.

5.5.4   Limitations

There were also likely some biases resulted from being a participant in the study. Even though the participants were only provided with limited information about the purpose of the study, the description given within the consent form could have shaped their expectation for the experience. Another bias stemmed from participants being purposefully recruited as experts within their field of interactive exhibits and culture spaces, and as such they were inclined to provide a lot of feedback on the quality of the installation. This feedback is exceptionally useful, however the focus on providing a critic might have distracted some participants from being in a more experiential state within the experience. That is also probably the reason why usability was the most frequently commented on topic in the interviews, whereas usability concerns were not as prominent in previous tests of the prototype with a different population. Having to wear the goosebump camera sensors also might have presented a bias in participant's expectations. Only one participant had explic-

itly discussed how she was expecting something to jump out at her to give her goosebumps, but other participants possibly have also formed some expectations.

5.5.4.1 Lack of goosebumps

A low number of occurrences of goosebumps in our study is likely associated with a number of usability issues that this prototype had, which would need to be improved for future studies, including the resolution of the HMD, the quality of models and soundscape. However, it is also possible that some participants might have had goosebumps or shivers that did not register on our camera. There are limitations to our second prototype goosebump recording device used in this study. The arrector pili, a smooth muscle that cannot be consciously controlled, is responsible for the erection of individual hairs making up the goosebumps. We hypothesize that when a structure of noticeable weight is placed on this smooth muscle, it may inhibit the muscle's activation. In this case, the goosebump recording device touches nearby skin that is being recorded, and our concern is that goosebumps that would have otherwise appeared are thus suppressed by the recording device itself. The first prototype used in Quesnel and Riecke (2018) was bulkier, but instead touched the underside of the forearm, leaving the top of the forearm (which was the surface being recorded) out of contact. This may have allowed for that study's 43% goosebump elicitation rate in line with previous studies also between 40-43% (Benedek and Kaernbach (2011); Wassiliwizky et al. (2017); Sumpf et al. (2015)). Our most recent goosebump instrument prototype now records the back of the participant's neck, and the decision for this location is threefold: 1) many individuals with the rare ability to voluntarily elicit goosebumps have reported the sensation starting on the back of the neck (Benedek et al. (2010); Heathers et al. (2018)); this location is reported more than any other site (71.88% on back of neck vs 21.8% on arms) (Heathers et al., 2018). According to Heathers et al., the back of neck is also reportedly the strongest place to feel the goosebump sensation. 2) The hair follicle density on the back (including upper back/neck) and upper arm is twice as much as the forearm, thorax, thigh, and calf (Benedek et al., 2010), therefore the denser location may be more obvious. 3) As suggested by Wassiliwizky et al. (2015) chills/goosebumps may not always be expressed bilaterally on both arms, or both legs, meaning a single instrument on a limb may not catch the phenomenon in the event it occurs on the opposite limb. That said, researchers have also reported the lower leg as a reliable location for goosebumps, with Wassiliwizky et al. (2017) obtaining a 40% elicitation rate. However, the nature of VR interfaces often requires the use of arms and legs to move freely, and unencumbered by distracting, wearable instruments. This interface concern is another reason for our decision to pursue recording of the back of neck opposed to limbs; an instrument can be mounted in a rigid position in this location and not require touching of the skin.

Interestingly in this study, the participant that had the moment of shivers, had a slightly negative connection between Self and Nature. Even though this is only one instance and no

strong inferences can be drawn from it, this could be an indication that participants with a lower connection of Self and Nature could be more likely to have a stronger emotional reaction from observing awe-inspiring view of the Earth as they would have a stronger need for accommodation than participants who already feel a strong connection to nature and the view of the Earth easily assimilates into their current worldview (Gaggioli, 2016; Lorini and Castelfranchi, 2007). However, the relationship between the strength of awe and the need for accommodation was not supported in the study by Schurtz et al. (2012), where the measure of the need for accommodation did not predict the measure of awe. However, their study was investigating awe in the social context as opposed to nature and their measure of the need of accommodation wasn't validated, and as such, the results do not eliminate the possibility of the relationship between the degree of the need of accommodation and the intensity of awe.

5.5.4.2 Gender effects

Noteworthy, some gender differences were apparent in the descriptions of the experience and evoked emotions in the interviews, which is aligned with the research on gender differences in use of affective language (Goldshmidt and Weller, 2000). On average our male participants seem to be more reserved with the emotional words, especially when talking about fear or delight, they rather tend to focus on engagement and curiosity and more operational aspects of the experience and less on the experiential; while female participants will more easily engage in conversations about feelings and their emotional reactions to the environment. This gender difference might be important to keep in mind when analyzing the interviews, as the affective dimension of male's experiences might be less obvious or striking, but there are still often some indications of it. For instance, sometimes when asked about a moment, that seemed to have produced an emotional response (based on participants mentioning it or the researcher observing them vocalizing or changing breathing pattern while in the experience) in a male participant, they might respond with *"I don't know how to explain..."* and continue onto describing their actions instead of their feelings in order to explain that moment to the interviewer. Micro-phenomenological interviews might be useful for guiding male participants to bring their attention to the affective dimension of their experience and assist them in identifying and verbalizing their feelings.

5.5.5 Comparing the interview methods

The two interview techniques: cued-recall debrief and micro-phenomenology were successful in helping participants to provide a detailed account of their experience, providing a more thorough and deep description than open or semi-structured interview or a survey could have achieved. This is supported by reports of some participants who noted that the interview procedure helped them process and pay attention to their past experience, and is also evident from comparing the richness and precision of the descriptions collected in this study with our

earlier pilot tests, where we used semi-structured interviewers. As expected, the cued-recall method was a little better at encouraging the feedback about the system/installation and the micro-phenomenology the feedback about the progression and dimensions of individual experience. However, both methods have their own limitations: the micro-phenomenological interviews are zooming in only on a few moments of the experience, and thus don't address experience as a whole and provide little light on the portions of the experience that were not chosen as moments of interest, while cued-recall debrief doesn't provide as much depth to the descriptions and is less rigorously structured, meaning that there might be more bias introduced from interviewer's questions. We can also observe some trends in what type of responses are more likely to be provided within a given interview: for instance, from Figure 5.7 we can see that body change responses are more likely to be reported in a micro-phenomenological interview, while intellectual appreciation in a cued-recall interview. This is reasonable to expect given the structure and focus of each type of the interview: micro-phenomenology narrows its focus to the very specific short moments and investigates different dimensions of the experience, that normally remain unnoticed, such as bodily sensations, while cued-recall operates on higher overview level and is more likely to prompt the interviewee to describe their attention allocation and the reasoning behind it. For future work, we would like to combine both methods and at first perform a cued-recall of the whole experience and follow up with a micro-phenomenological interview of significant moments identified during the cued-recall.

5.6   Conclusions and Future Work

This study indicated that a virtual experience, inspired by the Overview Effect and designed to elicit awe, despite some usability concerns, was able to invite minor transformative experiences in some participants, including the main aspects of it: the appreciation of beauty and vastness (Keltner and Haidt, 2003), realization of interconnectedness (Yaden et al., 2016) and a potential intent to change one's behavior based on that realization (Stepanova et al., 2018b; White, 2014). We have also discovered some unique opportunities VR technology affords for a design of a profound experience: the opportunity to create a journey taking the participant through induction of a minimal fear in a safe environment and a following release from it; and the opportunity to explore the mind-body connection and the effects of shifting the strength and the locus of control within it.

Giving the reliance of this line of research on deep emotional responses and how much the individual background and expectations can shape this experience, we see two important directions for future development of this project: first, extensive demographics information and interviews are required when using qualitative methods of assessment in order to be able to explain results in the context of a personal experience; second, more flexible and

personalizable experience, that can adapt to the immersant's state is desirable and will be able to create a smoother journey to the desired emotional response.

In the future work we are planning to integrate more physiological sensors (Quesnel et al., 2018a) and automatizing the goosebump detection (Uchida et al., 2018), combined with micro-phenomenological and cued-recall interviews of the events identified from the physiological data. This will allow us to develop deeper understanding of progression of one's experience in an immersive affective installations, and identify what elements of the journey might be triggering the specific responses in the participants.

Virtual reality experiences, inspired by natural phenomena, provide us with an exciting opportunity to study an individual's experience in detail and establish the relation between the experience and the environment. However, we argue that a profound experiences mediated through technology should be seen as its own category of phenomena that requires more exploration. To build this body of knowledge more studies need to explore in detail how profound affective VR personal experiences unfold. This knowledge would inform future design of positive transformative VR experiences that would make such desirable experiences more accessible to the public.

Table 5.1: Comprehensive summary of themes coded in the interview data, with the prominent themes reported in this chapter bolded

	Affects	**Positive**
		Negative
	Emotional states	**Fear / Discomfort**
		Safety / Trust / Comfort
Emotions & Feelings		Immersion and Engagement
	Bodily sensations	**Internal bodily reactions**
		Reflexes
		Vection
		Weightlessness / Floating
	Mini-shifts	**Connectedness**
		Renewed conceptual knowledge
		Vastness and small-self
Cognitive shifts & Processes		**Intent of behavioral change**
	Processes	Anticipation
		Imagination
	States and Constructs	Experiential vs. Analytical
		Agency / Self-relevance
		Embodiment
		Presence ('being there')
	Orienting	**Anchoring**
		'Where am I?'
		Seeking a goal
		Justifying / Making sense
Acts & Intents	Inner tensions and debates	Exploring vs. Following
		'Taking it in' vs. Goal-oriented
	Thinking of / testing the system	Fear to miss something
		Pushing to the edge
		Trying to predict what is coming
	Personal background	**Familiarity vs. Novelty**
		Love or hate of the environment
External (to the system) factors		Comparing to other mediums
	Expectation	Participant bias
		Realistic representation
	Usability	Navigation Interface
		Quality of models
		Collisions
		Cybersickness
		Physical space and objects
System / Experience design	Narrative	Transitions
		Ending
		Sprite character
	Attributes of the environment	Lighting
		Sound
		Open vs. Claustrophobic
		Realistic vs. magical

Chapter 6

General Conclusion

This thesis has described the process through which immersive VR experiences for invitation of transformative experiences can be developed. Even though no profound transformation as the result of the designed VR experience was achieved yet, the viability of its potential is supported by the results of the study. The "AWE" installation was able to elicit some affective responses and showed indications of some components of awe experienced, it also induced a few minor cognitive shifts in some participants. These components of the participant's experience intersect with astronauts' experience of the Overview Effect, supporting the hypothesis that it might be possible to elicit a version of the Overview Effect here on Earth through the medium of VR introducing a virtual Overview Effect, that could have similar desired outcomes as the Overview Effect experienced in space.

The Transformative Framework, introduced in the second chapter of this thesis, provided a useful structure for evaluating the progression of the transformative experience. If we look at the results reported in the Chapter 5, the majority of the comments coded in the participant's interviews correspond to the first stage of the framework (perceptual experience and resulting emotions of awe and wonder), followed by fewer codes representing the second stage of cognitive shift (realization of interconnectedness), and only single response illustrating the last stage – behavioral change. This shows that *"AWE"* installation still requires more iterative development to assist the immersants with progression from the first stage of the transformative framework through the last two stages. This would mean, that the developers of the experience should attempt to facilitate the process of accommodation to advance from the perceptual experience stage into the cognitive shift stage. Accommodation process could possible be facilitated though encouraging introspection throughout the design of the virtual journey or at the exit out of it, as well as providing a social space for discussion (Schlitz et al., 2010), where participants can reflect on and accommodate their experience. In order to assist with progression from the stage of cognitive shift to the behavioral change, we would need to facilitate the discovery of the conflict between the new worldview and old behavior (Auer and Griffiths, 2018); to start, we could try to bring participant's attention to the consequences of some exemplar behaviors consistent with the

acquired attitudes (Consolvo et al., 2009), e.g. recycling or minimizing use of plastic. The framework itself needs to be developed more as well, to include the external factors that will effect the transition between the stages, such as personal background and traits and high level intentions (Pacherie, 2008).

The guidelines for the design of virtual experience of the Overview Effect, outlined in Chapter 4, were partially supported by the study, but only a few of them were implemented through the design and evaluation of *"AWE"*. The importance of facilitating a personal connection to an aspect of a virtual environment and inclusion of initial fear in the emotional journey, proposed as the design guidelines based on the analyses of astronauts' interviews, appear to be effective in contributing to the desired experience in the immersants of *"AWE"*. More of the proposed guidelines have to be tested and verified. It is challenging to include and test all guidelines, especially, since in order to be able to assess their impact, they have to be examined independently from each other, which is not feasible in the context of a complex target phenomena such as the Overview Effect, where no single potential precursor would likely be sufficient to trigger the full experience by itself. A fairly complex system of evaluation methods combining physiological data with in-depth qualitative phenomenological analyses in the context of controlled and reproducible VR environment could be a good start in untangling the node of various components of the transformative experience and its precursors, triggers and effects.

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Stepanova, E. R., Quesnel, D., and Riecke, B. E. (2018a). Space – a virtual frontier: How to design and evaluate a virtual experience of the overview effect promoting the feeling of connectedness. *Frontiers in Digital Humanities*. (under review).

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Appendix A

Authors contributions to the manuscripts

Chapter 2: Stepanova, E. R., Quesnel, D., & Riecker, B. E. (2018, May). Transformative Experiences become more accessible through Virtual Reality. In *Proceedings of IEEE Virtual Reality*, Reutlingen, Germany. (in print)

Stepanova wrote the first draft of this manuscript. Quesnel made the figure. Stepanova and Quesnel and revised the manuscript together. Riecke provided feedback and guidance on the manuscript.

Chapter 3: Stepanova, E. R., Quesnel, D. & Riecke, B. E. (2018). Space a virtual frontier: How to design and evaluate a virtual experience of the Overview Effect promoting the feeling of connectedness. *Frontiers in Digital Humanities.* (under review)

Stepanova wrote the large majority of this paper. Quesnel has wrote the sections on awe, Gallagher's work and piloerection. Riecke, Quesnel and Stepanova revised the manuscript.

Chapter 4: Quesnel, D., Stepanova, E. R., Aguilar, I., Pennefather, P. & Riecke, B. E. (2018, August). Creating AWE: Artistic and scientic practices in research-based design for exploring a profound immersive installation. In *Proceedings of 2018 Game, Entertainment and Media Conference(GEM).* IEEE. (accepted)

Quesnel and Stepanova wrote the majority of this paper with an approximately equal amount of contribution between the two of them. Aguilar contributed to the section on sound and navigation. Pennefather provied feedback and suggestions on the manuscript as well as the first draft of the figure of the structure of awe phenomenon. Stepanova, Quesnel and Riecke revised that figure. Quesnel made all the figures for this manuscript. Riecke provided feedback and contributed to the revisions of the paper. All of the authors contributed to the decisions made in the process of the design of the immersive installation.

Chapter 5: Stepanova, E. R., Quesnel, D., & Riecke, B. E. (2018). Understanding AWE: Can a virtual journey, inspired by the Overview Effect, lead to an increased sense of interconnectedness? *Frontiers in Digital Humanities.* (in preparation).

Stepanova wrote most of this paper. Quesnel and Stepanova each coded the qualitative data independently and then discussed their codes to achieve agreement on themes. Quesnel performed the analyses and wrote the section on Gallagher's categories of awe. Quesnel reviewed and edited the manuscript. Riecke provided feedback and suggestions to the manuscript. All of the authors contributed to the design of the study.