

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

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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.

Index Terms—virtual reality, awe, interconnectedness, well-being, research-based design

I. INTRODUCTION

Awe-inspiring experiences can lead to shifts in perspective, changes to moral attitude, and in how people see their relationship with the world [1]. 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 [2]. Furthermore, awe tends to transcend the attention beyond the individual self and towards the environment, providing therapeutic and social benefits; a study by Rudd, Vohs, and Aaker [3] 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 [4], which are responsible for the initiation and persistence of pathologic pain [5].

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 [6]. 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 [7]. 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 [8]. 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.* [9], 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 [10], [11], VR is also physically immersive through augmentation/replacement of stimuli to an immersant’s senses via the VR technology [12], and sensory immersive through blocking out stimuli from the physical world [10], [11]. 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 [13].

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” [14]. 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 [15]. 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 [16]. 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.

II. RESEARCH-BASED DESIGN

A. 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 [17], 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.

B. 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 awe and previous work on designing affective immersive experiences. Understanding what awe is, and is not is key, with Gallagher *et al.* [18] forming a working definition of awe: “a direct and initial experience or feeling when faced with something amazing, incomprehensible, or sublime” (p. 6).

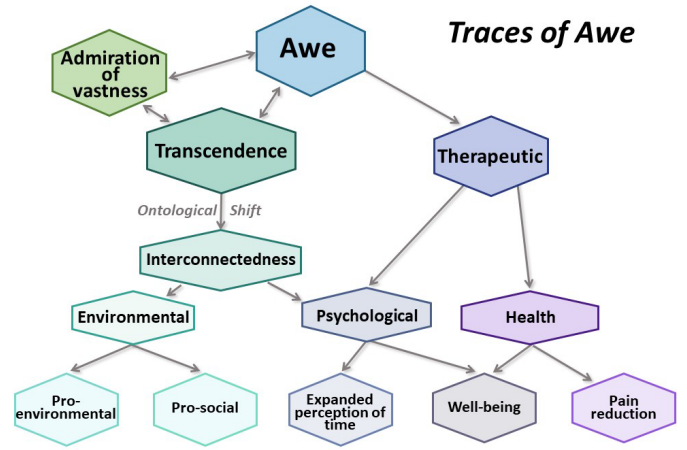


Figure 1. The many components and outcomes of an awe-inspiring experience.

Gallagher *et al.* created this definition through textual analysis of thousands of astronauts and study participants awe-inspiring accounts, and in integrating empirical research on awe. We created a typology of awe (Fig. 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 [6]. Previous work by Chirico *et al.* [19] 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 [20]. 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.

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 [21]. 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* [22]. 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 re-

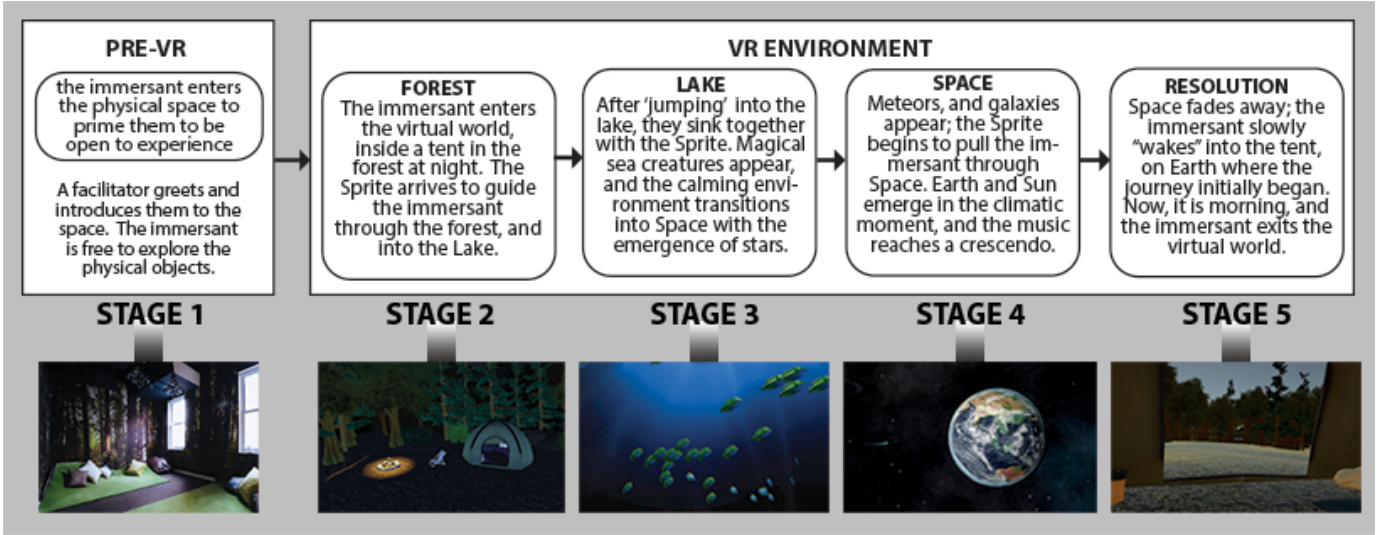


Figure 2. The five-stage journey the immersant proceeds through, starting with the Pre-VR environment, which blends into the VR environment.

sponse; Gorini *et al.* [23] 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 [24]. 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.

III. DEVELOPMENT AND DESIGN

A. 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. 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.

B. 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.

C. 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 [25] as well as forming a participatory ritual for participants that can assist in introspective experiences [26]. 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.

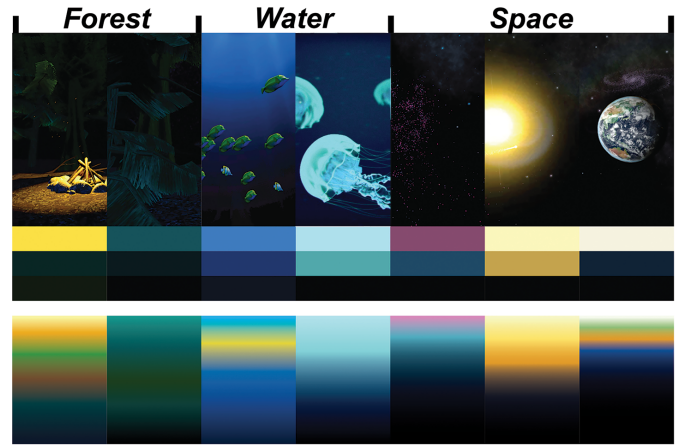


Figure 3. The colour mood journey of AWE in the virtual environment.

D. 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* [27], a dreamy environment that creates a sense of magic. The 2012 video game *Journey* [28] 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 3). Colours are understood to elicit specific moments of affect, contributing towards an overall

mood [29] 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.

E. Soundscape

To better understand the emotion of awe, studies have explored the relationship of music listening and awe elicitation[30]. 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 [31]. 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 immersant 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 [32].

F. 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



Figure 4. An immersant with the custom navigation interface.

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).

G. 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 [33]. This interface also reduces the potential risk of motion sickness caused by the conflict between visual and vestibular cues

[34]. 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 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). 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 [35]. 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 [36]. 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 environment. 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.

H. 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.

IV. 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 [37], [38] 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 [39].

A. Phenomenological Interviews

1) *Cued-Recall Debrief*: Immediately after the immersive experience, an immersant undertakes a cued-recall debrief, [40] 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.

2) *Micro-phenomenological Interviews*: During a micro-phenomenological interview [41], 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 immerant 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 prototyping. 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 [6], [2].

B. Physiological Measures

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

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.

2) *Goose bumps and Shivers*: Goose bumps and shivers are an objective and specific marker of occurrences of awe [31], [42]. 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 [20]. 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 [43].

C. 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.

D. 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 [44]. Three quarters of immersants in the third prototype phase showed a positive connection with nature after experiencing AWE.

V. 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 imperative 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 meetups 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.

VI. ACKNOWLEDGMENTS

We thank our collaborators NGX Interactive, and the Drifting Pugs team from the Center for Digital Media for their invaluable support and contributions to this project.

REFERENCES

- [1] D. Keltner and J. Haidt, "Approaching awe, a moral, spiritual, and aesthetic emotion," *Cognition & emotion*, vol. 17, no. 2, pp. 297–314, 2003.
- [2] J. E. Stellar, A. M. Gordon, P. K. Piff, D. Cordaro, C. L. Anderson, Y. Bai, L. A. Maruskin, and D. Keltner, "Self-transcendent emotions and their social functions: Compassion, gratitude, and awe bind us to others through prosociality," *Emotion Review*, vol. 9, no. 3, pp. 200–207, 2017.
- [3] M. Rudd, K. D. Vohs, and J. Aaker, "Awe expands peoples perception of time, alters decision making, and enhances well-being," *Psychological science*, vol. 23, no. 10, pp. 1130–1136, 2012.
- [4] J. E. Stellar, N. John-Henderson, C. L. Anderson, A. M. Gordon, G. D. McNeil, and D. Keltner, "Positive affect and markers of inflammation: Discrete positive emotions predict lower levels of inflammatory cytokines," *Emotion*, vol. 15, no. 2, p. 129, 2015.
- [5] C. A. Dinarello, "Proinflammatory cytokines," *Chest*, vol. 118, no. 2, pp. 503–508, 2000.
- [6] M. N. Shiota, D. Keltner, and A. Mossman, "The nature of awe: Elicitors, appraisals, and effects on self-concept," *Cognition and emotion*, vol. 21, no. 5, pp. 944–963, 2007.
- [7] C. J. Wilson and A. Soranzo, "The use of virtual reality in psychology: A case study in visual perception," *Computational and mathematical methods in medicine*, vol. 2015, 2015.
- [8] M. Usuh, C. Alberto, and M. Slater, "Presence: Experiments in the psychology of virtual environments," Tech. Rep., 1996. [Online]. Available: http://www8.cs.umu.se/kurser/TDBD12/VT07/articles/precense-paper-teap_full96.pdf
- [9] C. M. Coelho, J. Tichon, T. J. Hine, G. Wallis, and G. Riva, "Media presence and inner presence: The sense of presence in virtual reality technologies," in *Emerging Communication: Studies in New Technologies and Practices in Communication*. IOS Press, 2012, vol. 9, pp. 25–41.
- [10] L. Ermi and F. Mäyrä, "Fundamental components of the gameplay experience: Analysing immersion," in *DIGRA*, Vancouver, Canada, 2005.
- [11] J. Vidyarthi, "Sonic Cradle: Evoking Mindfulness through Immersive Interaction Design," Master's thesis, Simon Fraser University, Surrey, BC, Canada, 2012. [Online]. Available: <https://theses.lib.sfu.ca/thesis/etd7542>
- [12] W. R. Sherman and A. B. Craig, *Understanding virtual reality: interface, application, and design*, ser. Morgan Kaufmann series in computer graphics and geometric modeling. Amsterdam: Morgan Kaufmann, 2003.
- [13] G. Riva, T. Anguera, B. K. Wiederhold, and F. Mantovani, Eds., *From communication to presence: cognition, emotions, and culture towards the ultimate communicative experience*, ser. Emerging Communication: Studies in New Technologies and Practices in Communication. Amsterdam: IOS Press, 2006, no. 9.
- [14] F. White, *The overview effect: Space exploration and human evolution*. AIAA, 1998.
- [15] D. B. Yaden, J. Iwry, K. J. Slack, J. C. Eichstaedt, Y. Zhao, G. E. Vaillant, and A. B. Newberg, "The overview effect: Awe and self-transcendent experience in space flight," *Psychology of Consciousness: Theory, Research, and Practice*, vol. 3, no. 1, pp. 1–11, 2016.
- [16] A. Nezami, "The overview effect and counselling psychology: astronaut experiences of earth gazing," Doctoral dissertation, City, University of London, 2017.
- [17] T. Leinonen, T. Toikkanen, and K. Silvast, "Software As Hypothesis: Research-based Design Methodology," in *Proceedings of the Tenth Anniversary Conference on Participatory Design 2008*, ser. PDC '08. Indianapolis, IN, USA: Indiana University, 2008, pp. 61–70.
- [18] S. Gallagher, B. Janz, L. Reinerman, J. Trempler, and P. Bockelman, *A neurophenomenology of awe and wonder: Towards a non-reductionist cognitive science*. Springer, 2015.
- [19] A. Chirico, F. Ferrise, L. Cordella, and A. Gaggioli, "Designing Awe in Virtual Reality: An Experimental Study," *Frontiers in Psychology*, vol. 8, 2018.
- [20] D. Quesnel and B. E. Riecke, "Awestruck: Natural interaction with virtual reality on eliciting awe," in *3D User Interfaces (3DUI), 2017 IEEE Symposium on*. IEEE, 2017, pp. 205–206.
- [21] C. Davies and J. Harrison, "Osmose: towards broadening the aesthetics of virtual reality," *ACM SIGGRAPH Computer Graphics*, vol. 30, no. 4, pp. 25–28, 1996.
- [22] M. Prpa, K. Tatar, J. Francoise, B. E. Riecke, T. Schiphorst, and P. Pasquier, "Attending to Breath: Exploring how the cues in virtual environment guide the attention to breath and shape the quality of experience to support mindfulness." Hong Kong, China: ACM, June 2018.
- [23] A. Gorini, C. S. Capideville, G. De Leo, F. Mantovani, and G. Riva, "The Role of Immersion and Narrative in Mediated Presence: The Virtual Hospital Experience," *Cyberpsychology, Behavior, and Social Networking*, vol. 14, no. 3, pp. 99–105, July 2010.
- [24] P. Osborne, R. El Guerrab, D. Eisenmann, and C. Curtis, "The Making of "Pearl," a Google Spotlight Story," in *ACM SIGGRAPH 2016 Production Sessions*, ser. SIGGRAPH '16. New York, NY, USA: ACM, 2016, pp. 29:12–29:12.
- [25] F. Steinicke, G. Bruder, K. Hinrichs, A. Steed, and A. L. Gerlach, "Does a gradual transition to the virtual world increase presence?" in *Virtual Reality Conference, 2009. VR 2009. IEEE*. IEEE, 2009, pp. 203–210.
- [26] A. Kitson, T. Schiphorst, and B. E. Riecke, "Are You Dreaming? Designing for Introspective Experiences in Virtual Reality through a Phenomenological Study on Lucid Dreaming Practices," in *CHI '18: Proceedings of the SIGCHI conference on Human factors in computing systems (accepted full paper)*. Montréal, Québec, Canada: ACM, Apr. 2018.
- [27] Moon Studios, "Ori and the blind forest," 2015. [Online]. Available: <http://www.orithegame.com/>
- [28] thegamecompany, "Journey," 2012. [Online]. Available: <http://www.thegamecompany.com/journey/>
- [29] A. P. Shimamura, *Psychocinematics: Exploring cognition at the movies*. Oxford University Press, 2013.
- [30] L.-O. Lundqvist, F. Carlsson, P. Hilmersson, and P. N. Juslin, "Emotional responses to music: Experience, expression, and physiology," *Psychology of music*, vol. 37, no. 1, pp. 61–90, 2009.
- [31] J. Panksepp, "The emotional sources of "chills" induced by music," *Music Perception: An Interdisciplinary Journal*, vol. 13, no. 2, pp. 171–207, 1995.
- [32] M. H. Thaut and W. B. Davis, "The influence of subject-selected versus experimenter-chosen music on affect, anxiety, and relaxation," *Journal of Music Therapy*, vol. 30, no. 4, pp. 210–223, 1993.
- [33] E. Kruijff and B. E. Riecke, "Navigation interfaces for virtual reality and gaming: Theory and practice," in *Virtual Reality (VR), 2017 IEEE*. IEEE, 2017, pp. 433–434.
- [34] J. J. LaViola Jr, "A discussion of cybersickness in virtual environments," *ACM SIGCHI Bulletin*, vol. 32, no. 1, pp. 47–56, 2000.
- [35] Patrik Kunzler, "Limbic chair," 2018. [Online]. Available: <http://www.limbic-life.com/why-limbic/>
- [36] G. Riva, F. Mantovani, C. S. Capideville, A. Preziosa, F. Morganti, D. Villani, A. Gaggioli, C. Botella, and M. Alcañiz, "Affective interactions using virtual reality: the link between presence and emotions," *CyberPsychology & Behavior*, vol. 10, no. 1, pp. 45–56, 2007.
- [37] E. R. Stepanova, D. Quesnel, and B. E. Riecke, "Transformative experiences become more accessible through virtual reality," in *IEEE VR Workshop on Virtual and Augmented Reality for Good (VAR4GOOD)*. IEEE, 2018.
- [38] A. Gaggioli, "Transformative experience design," *Human Computer Confluence. Transforming Human Experience Through Symbiotic Technologies*, pp. 96–121, 2016.
- [39] E. R. Stepanova, D. Quesnel, and B. E. Riecke, "Understanding AWE: How a virtual journey can lead to increased connectedness," *Frontiers in Digital Humanities*, 2018, (in preparation).
- [40] T. Bentley, L. Johnston, and K. von Baggio, "Evaluation using cued-recall debrief to elicit information about a user's affective experiences," in *17th Australia conference on Computer-Human Interaction: Citizens Online*. CHISIG, 2005, pp. 1–10.
- [41] M. Bitbol and C. Petitmengin, "Neurophenomenology and the elicitation interview," *The Blackwell Companion to Consciousness (2nd edition)*. Wiley & Sons, 2016.
- [42] M. Benedek and C. Kaernbach, "Physiological correlates and emotional specificity of human piloerection," *Biological Psychology*, vol. 86, no. 3, pp. 320–329, Mar. 2011.
- [43] D. Quesnel and B. E. Riecke, "Are You Awed Yet? Exploring Interactive Virtual Reality for Positive Emotions," *Frontiers in Psychology*, vol. 8, 2018, (in preparation).
- [44] P. W. Schultz, C. Shriver, J. J. Tabanico, and A. M. Khazian, "Implicit connections with nature," *Journal of environmental psychology*, vol. 24, no. 1, pp. 31–42, 2004.