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Exploring Virtual Realities: A Study on Awe Response

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Abstract.

With the rise of Virtual Reality (VR) technology, it opened an opportunity to explore its potential such simulation, training, entertainment, and emotion elicitation such as awe. Awe is a complex emotion that often evokes through the feeling of vastness and challenges one's understanding of the world [7]. Eliciting awe has its benefits such as enhancing connections between people, foster empathy, and improve health. For this study, we created a VE that will immerse the participants in Petra, one of the new seven wonders of the world. Reason for choosing Petra comes down to its intricate design, architecture, and perfect human craftsmanship. 10 participants with different levels of experience in video games, virtual reality, and other experiences, performed the experiment using HTC VIVE Pro headset. Participants' subjective data will be collected through questionnaires and physiological measurements will be taken using VU Ambulatory Monitoring Solutions (VU-AMS), this includes ECG (electrical activity of the heart), and ICG wavelength (electrical resistance of the chest). In return for the experiment, the measurements taken will be turned into valuable knowledge for better understanding of the relationship between awe and VR and its subsequent physiological and psychological impact.

KEYWORDS:

Virtual Reality, Virtual Environment, Awe, Elicitation, Presence, Immersion

1. Introduction

The popularity of virtual reality (VR) has been on the rise for decades. VR enables users to immerse themselves in a virtual environment (VE) created by a computer using a VR headset and controllers [1]. Initially VR was made for simulation and training purposes. As time progresses, VR technology has become more affordable and accessible leading to an increase in research on its other effects [2]. It has been discovered that VR offers benefits beyond simulation and training [3]. Numerous studies have explored the use of VR in exposure therapy, such as treating disorders and examining how it impacts user emotions [4, 5, 6]. However, emotions such as awe are relatively less studied, because historically most applications are more focused on emotions that are simpler to elicit and more directly impacted for the treatment phobia and mental disorders.

Awe is an emotional response that is often evoked from the feelings of vastness and challenges one's understanding of the world [7], often known to reduce self-centeredness and serves a vital social purpose [8]. VR on the other hand, have the ability to create VE that can evoke a sense of vastness that is controlled. This suggests that we have the potential to enhance connections between people, foster empathy, and improve health through the combination of awe and VR. Consider, for instance, a person with a disability who dreams of exploring different parts of the world. By using a VR headset, they can immerse themselves into the wonders of the world that may otherwise be inaccessible to them. The emotional and psychological advantages that arise from VR experiences can be truly transformative for people with disabilities and emotional disorders [9].

A virtual environment can be made to evoke any emotion ranging from sadness and fear to wonder, inspiration, and awe. These complex and powerful emotions can have implications for treating phobias as well as conditions like PTSD and depression [10]. Hence this experiment seeks to dive into the elicitation of awe using VR. By understanding the effects of awe on participants, we can explore its benefits and associated risks that come with it. Moreover, the development of awe eliciting environment provides a useful tools for medical professionals for the treatment of patients with phobias and other medical conditions.

2. Related Work

Virtual reality is a technology that has gained increasing interest over the decades. It allows users to interact with 3D content in a way that closely resembles real-world experiences [11]. Recent studies have shown that VR is highly effective in evoking emotions because of its strong capability in immersing users in a VE [12]. This immersion creates a sense of "presence" for the participants as if they are truly, inside the environment [11, 13, 15]. The immersive nature of VR intensifies responses, which enhances the overall use experience.

2.1. What is awe, its effect, and its relation to VR?

Awe is a complex emotion that has a wide-growing interest in the field of psychology. Awe is described as a mix of fear, amusement, wonder, and other various emotions, and is often triggered in front of something vast and powerful [16], referring to something so difficult for a person to comprehend that it needs to be accommodated by expanding their frame of reference [17]. This emotion can be evoked by stimuli such as works of architecture, vast natural landscapes, and mythical fantasy worlds. There are however two common conditions that awe arises from, vastness and need for accommodation [18]. Vastness implies great physical size, in this usage 'vast' describes any stimuli that challenge one's accustomed frame of reference in some dimension. This dimension can be vastness in physical space, in time, in number, in the complexity of details, and any other senses human experience [18]. What is important to note about vastness is that it refers to stimuli that dramatically expand the viewer's normal understanding of the object.

This awe emotion has several notable effects on human cognition, behavior, and well-being:

- Prosocial behavior: Awe has been found to be associated with an increase in acts of kindness and selflessness according to a study conducted in 2015 [8]. Participants who experienced awe showed an inclination towards generosity and altruism. This kind of behavior reflects tendencies and promotes a sense of interconnectedness.
- Perception of time; Research suggests that experiencing awe can alter our perception of time, making us feel like we have available time. This shift in perception leads to increased satisfaction and a greater willingness to assist others [19].
- Sense of connection and well-being; Awe through its influence on behavior fosters a sense of connection with others and the world, at large counteracting feelings of isolation [20]. Consistently experiencing awe is also linked to improved well-being, reduced symptoms of depression, and higher life satisfaction levels [21].

Virtual Reality offers an opportunity for exploration. Creating a potential to elicit awe, while not every VR experience are awe eliciting, the immersive nature of VR allows for the development of detailed and sometimes surreal environments that can make objects appear larger than they are, which potentially could trigger a feeling of awe. However, it is important to note that to elicit awe in VR depends on multiply factors, including design, user perception, and context of the VE [22].

A study conducted by Chirico and Gaggioli highlighted the ability of VR to evoke feelings of awe in users. Through designing VR environments specifically aimed at invoking a sense of vastness and wonder, the experiment demonstrated that virtual experiences in VR can indeed stimulate awe-inspiring emotions [23]. This finding suggests that VR can be effectively utilized as a controlled medium for feelings of awe.

The incorporation of awe into applications involving VR has shown effects. For individuals with disorders such as depression incorporating elements of awe into their VR experiences has been found to enhance feelings of connectedness and wonder. In 2016 a study was conducted where participants engaged in VR therapy sessions that aimed to evoke feelings of awe. The results of this experiment showed a decrease in loneliness and an overall improvement in the well-being of the participants [24].

One of the first attempts to use VR to induce awe was made by Reinerman Jones et al. (2013) [25]. These researchers explored how participants experienced a space perspective, commonly known as the 'overview effect' [26]. The study emphasizes that visual stimuli, and participant's attention during the experiment, all play roles in creating feelings of awe. It is worth noting that individuals with spiritual beliefs may have diverse experiences during the experiment but are not limited from experiencing awe.

2.2. How to elicit awe:

VR has been proven to be useful in emotion elicitation because of its ability to create an illusion of 'being present'. This creates the opportunity for awe elicitation through VR, allowing participants to experience and connect with vast, realistic, environments that might be challenging or impossible to achieve in the physical world.

Presence refers to the feeling of 'being there' within the virtual environment. 'Being there' marks the foundation of defining the experience of VR, despite being physically in the environment. The strength of the "presence" a user feels in the environment improves the effectiveness of the VR application is at evoking a particular emotion [30]. However, this sense of presence is subjective, research has shown that different participants feel a presence at different levels in the same immersive VE. However, multiple research projects back the result of increasing immersion (such as better details, realistic audio) in VE increases the presence in participants [12, 34, 35, 36]. A review of several relevant literature finds three interrelated but distinct conceptualizations of presence. Each of these conceptions represents one or more aspects of presence, they vary considerably but share a central idea.

- Social Presence: To some scholars, presence is the point where the participants feel sociable, personal, warm, and interconnected when communicating with other people. Social presence is related to two important concepts of non-mediated communication principles of intimacy and immediacy [37, 38, 39]. Intimacy refers to the physical proximity, amount of smiling, body movement, and other behaviors that create an intimate equilibrium in interpersonal interaction between 'getting close' and 'maintaining distance' [37]. Other researchers have included behaviors such as body gestures and facial expressions [40, 41]. Increasing the social presence in VE creates more actional changes in participants and therefore adjusts the overall level of intimacy. Immediacy is the sense of closeness in user interaction. This psychological immediacy is affected by the choices of language, intimacy behavior, and medium for interaction [39, 38, 44], Because of such behavior, it is only logical to expect immediacy and social presence to be correlated.
- Physical Presence: The fundamental idea is that participants who are experimenting with VR should be more engaging in the virtual environment than the surrounding physical world [12]. In an analysis conducted in 2000 involving 63 items that entered a principal axis factoring (PAF) analysis, they found four factors that contribute to the sense of physical presence in participants [45]: Physical space, which was counted by 14.2% of the variance. First, Physical space, is defined as 'I have a sense of being in the scenes displayed', 'I felt I was visiting the place', and 'I thought that I was about to touch the object'. These items indicated a sense of physical space in the virtual environment. These factors encapsulate the definition of presence and were consequently labeled 'Sense of Physical Space'. Second, engagement, explained by 11.1% of the variance. Defined as 'I felt involved in the virtual environment', 'I enjoyed myself', and 'my experience was intense'. These items suggest participants are involved and enjoy the content, consequently labeled 'Engagement'. Thirdly, naturalness explained 7.6% of the variance and was characterized by questions including: "Virtual environment looks realistic to me', and 'The characters and objects are solid to me'. These variables caused participants to feel alive in the virtual environment therefore labels 'naturalness'. Lastly, the negative effect was explained by 5.4% of participants. This is characterized by the items of physiological reaction such as 'I felt dizzy', I felt nauseous,' and 'I felt like I had a headache'. This factor is labeled as a 'negative effect.
- Self-Presence: When something has physical contact with our body, we feel the contact at the same place that we see it. This is the normal correlation between two sensory streams. However, if this sensory stream is changed, it creates an asynchrony between felt and seen touch. There are numerous studies on this phenomenon, one famous experiment is the 'rubber hand' experiment [46, 47, 48, 49, 50]. This experiment involves the participant having one hand obscured from view,

the researcher will simultaneously stroke with a paintbrush on both the participant's hidden hand and the rubber hand, this procedure aims to manipulate the participant's brain to treat the rubber hand as if it is his actual hand. After several synchronous, participants will assign the rubber hand as their actual hand, even though they are intellectually aware it is not their real hand. This phenomenon suggests the brain can be manipulated to think something is real but not actual. Which is the critical point of self-presence. Understanding the principle behind the 'rubber hand' theory can serve as the foundation for VR. For instance, in VR, to achieve a sense of self-presence. The participant must feel as if they are immersed in the environment, by involving multiple sensory feedback. Designers can create more convincing VE leading to a stronger sense of self-presence [12, 51, 52].

Virtual Reality is capable of inducing emotions such as awe in users. Designers not only design around presence for immersing participants into the virtual environment, but also create interconnection, interaction, and self-awareness within these virtual environments. However, there are still uncertainties regarding the methodology for achieving awe in virtual environments and how different types of awe-elicitors may experience the same awe-eliciting environment. To strengthen the analysis of eliciting emotions, physiological measures can stretch beyond traditional questions and include measures of parasympathetic activation or withdrawal, which relates to heart rate, which is one of the most common practices in the current literatures [28]. Involving such measurements strengthens the understanding of the kind of awe induced.

3. System Development and Implementation

3.1. Overview

3.1.1. Controls
Before the start, the user was taught how to use the VR headset with their assigned controls. The user was taught how to navigate, look around, and teleport to their desired destination. The user is only able to use the headset and both D-pads for this experiment.

3.1.2. Tutorial room
This is where the user will learn the controls for VR. There are guides in the game that help users understand the controls and also researchers give verbal guides if participant need further information to understand the controls before the actual experiment. The room is shown in Appendix 1.

3.1.3. Petra canyon
The user was placed in a canyon before entering they can see Petra. They were asked to test the controls they learned again to make sure they were ready for the experiment. This is shown in Appendix 2.

3.1.4. Petra
This is where the user was exploring. They can teleport to different locations and view Petra from different angles. However, the user won't be able to interact with anything in the game besides exploring VE. This is shown in appe

3.1.5. Safety measures
Safety measures are in place to ensure the well-being of the participants during the experiment. The participants can withdraw consent anytime throughout the experiment without reason. All participants with anxiety and other mental issues are excluded from the experiment for their safety. This is so that the best precautions are taken place to prevent any health risks such as motion sickness, disorientation, and other potential health risk.

3.2. Requirement gathering and analysis.

Ensure that all requirements are correctly gathered for the VE and user studies. First, we have consistent meetings with our supervisor to ensure that we are on track with the project scope. The supervisor was advising us on the tools, tips, ideas, and feasibility of the approach. Second, we had a meeting with a group of postgraduate students to gain more opinions regarding the project scope and approaches to use during the development. Thirdly, a UX design of the project was given to the supervisor for deeper insight into the design before the initial development of the project. Finally, during the development, a demo was demonstrated to the second reader to gain third-party opinion regarding the development of the VE.

The project scope has changed at various times during the development. This is largely due to a lack of understanding of the Blender tool and the wrong approach when developing the model. This includes cutting the model into smaller pieces of the model, decimating the g model 20x, using the wrong textures, unable to import the model properly into Unity.

As more requirements are gathered, more risks are identified before and during development. The risks obtained will be shown in Appendix 4 as a risk assessment table.

3.3. Project phases

There are several phases that the project has undertaken during its development. After each phase, there's an evaluation of the phases with the supervisor to ensure that feedback can be collected before the next experiment.

Phase 0: Getting the model and setting up the development process.
The model of Petra is provided by the Zamani Project in the form of a polygon file format. This model consists of over 5 million faces and covers the whole Petra landscape. The latest Blender is used to import and work on the model.

Phase 2: Gathering scope.
Before the start of the initial development, a meeting with the supervisor and postgraduate students was held to gain a better understanding of the project priorities. The following points are mentioned:

- Heuristic evaluation must be performed throughout development.
- It is hard to create a realistic animal appearance when viewed up close.
- Too much interaction may create an unrealistic experience if not done correctly.
- A sense of scale of the objects is a must consideration for awe inducting experience.

Requirements of the project are also changed throughout development, due to different testing and people's suggestions. These suggestions are noted and added to the backlog of the project.

Phase 3: Development
The project now moves into development, from basic displaying the model to enhancing visual realism. This phase is crucial for immersing the user into the VE. According to the scope gathered, the first main priority is adding textures and mapping to the model and Blender is used for this purpose. High-resolution textures,

normal mapping, and height are mapped onto the model to emulate real-world scenery. These texture mapping are intricate tools that can mimic bumps, and indentations on surfaces without additional computation power. Ambient and roughness mapping are used to show how each surface should react to light, adding another layer of realism. Finally, lighting is a critical aspect that greatly influences the realism of the environment. World lighting is applied to the model, creating a realistic shadow effect that contributes to the realism in the VR.

Phase 4: Testing before user testing
Testing is a crucial part of the experiment. This involves testing and evaluation of the development and ensuring the project meets all requirements defined in scope, including user immersion and awe induction.

Constant heuristic evaluation is carried out throughout the development. These evaluations are critical and improve the immersive experience and presence for the user. The heuristic evaluation invented by Nielson and Molich is followed throughout development. Designing the best possible virtual environment that induces awe emotion.

Blender uses no code, therefore there is no code validation required for this process. However, quality checks are in place for model, texture, and lighting to be inspected such that they meet the scope of the project. This method involves collecting multiple images of Petra taken by the camera and making comparisons between the photo and the model. Making the right adjustments to the photos to achieve the best realism possible.

Before any user testing, a series of pilot tests were conducted to ensure that the VE was fully functional before any user testing. The pilot testing consisted of 3 people. Each person has agreed to participate and allow electrodes to be applied. They are informed of the aim of the project and have been asked to provide feedback after the testing. All the feedback collected is processed and saved in the project backlog for future implementation.

User testing is implemented after the pilot testing, more will be discussed in section 4.

4. Design and Implementation

4.1. Participants

10 Participants were recruited for this experiment made up of University of Cape Town (UCT) undergraduate students. To ensure the safety and reliability of the study, participants must meet specific criteria for them to qualify for the experiment.

- The person on the experiment day must not have any mental health disorder such as anxiety, or depression.
- The person is fine with electrodes applied to them, with no known allergies to the electrodes or sanitizers.
- They aware of potential side effects of VR such as motion sickness, dizziness, and disorientation
- Participants signed a written consent to participate in this experiment.

Recruitment was conducted via direct invitations sent through WhatsApp. They must fill out a Google Form with their knowledge and experiences of VR and inform participants of the experiment procedure. Appendix 5, 6, 7,8 contains the summary of the data collected from the Google form. The participants were not informed with the emotion that the experiment wanted to elicit; this was to ensure no conflicts of interest. The resulting participant pool was diverse with no notable trait of this.

4.2. Ethical considerations

University of Cape Town, Faculty of Science Research Ethics Committee, have approved the project with research ethics clearance. However, the research are conducted under the following conditions stated in the approval:

- Implement the measures described in your application to ensure that the process of your research is ethically sound; and
- Uphold ethical principles throughout all stages of the research, responding appropriately to unanticipated issues: Please contact me if you need advice on ethical issues that arise.

4.2.1. Justification for not disclosing the study's purpose.

In many experiments, especially within the psychology field, researchers do not disclose the main purpose of the study, this is an act of "deceptive" procedure prevention, leading to skewed or invalid results, preventing the researcher from finding the underlying reasoning behind certain behaviors. According to some studies, the behavior of the participants changes when participants are told the nature of the experiment, this is known as the 'demand characteristics' [55]. This misdirects the participants in behaving and responding to the experiments in a certain way that is in line with the nature of the experiment [56]. Disclosing such information will create a biased response creating a skewed result. To avoid this, a guide was followed to eliminate all possible biases that might occur during the experiment. This guide entails that the 'priming effect' must be avoided [57, 58], Priming is a technique for studying the role played by situational context in cognition, motivation, and behavior. Priming involves the participants being exposed to a particular stimulus (e.g., words or images) that will influence their behavior and reaction. This is the opposite of the purpose of the study as we want to see the emotion elicited by the participants when presented with an environment that is vast and immersive without prior information. To avoid the 'priming effect', the study does not disclose any information regarding the type of emotions that the experiment is trying to find; the participants are selected randomly regardless of their experience in VR, and the language used during the experiment is neutral to everyone without any persuasive effect [58].

In addition to eliminating the 'priming effect', the exclusion criteria were also used to ensure that the research would not cause severe distress to participants. Participants were informed with rights that they could withdraw from the study at any point during the experiment without reasoning. Before the study, the participants must sign a consent form declaring that they understand the possibility of side effects. In the end, they were invited to answer some questionnaires regarding their experiences with the virtual environment. In the end, some participants expressed that they had feelings of disorientation and dizziness after the experiment, however, all participants declared that they felt normal after some rest.

4.2.2. Other considerations

The participants in this experiment are paid R50 for participating in this experiment. The reason for this amount is that it is not large enough to be considered coercive and follows the standard UCT

research practice. This minimizes the possibility of participants joining the research for money and not the purpose of the research.

4.3. Measurement

Awe is a complex emotion that involves many different emotions and can be presented physiologically or behaviorally. Understanding such complex emotions requires understanding both the participant's subjective experience and physiological measurements [14, 27]. Both approaches will have their limitations in the metrics they exhibit. However, recognizing their limitations and merging both approaches can provide a more comprehensive understanding of the awe response. All measurements were taken in the same order, physiological measurements were taken using VU-AMS during the experiment and subjective measurements were taken in the form of questionnaires after the participants completed their experiment. This creates a standardized approach to conducting experiments with all participants and minimizes possible bias that the order of the measurement could generate.

4.3.1. Physiological measurement

To objectively measure the awe elicited by the user, we follow a review done by Sylvia Kreibig [28]. The experiment used VU - Ambulatory Monitoring System (VU-AMS) along VU-DAMS software and Python for recording and analysis of the data. In this experiment, we only measured heart rate (HR), respiration rate (RR), and respiratory sinus arrhythmia (RSA) during immersion. To identify the effect of awe, there are 2 phases that the user goes through. Tutorial sets the baseline measurement for the experiment; and Petra, this measurement will be compared to the baseline to see how measurements change as scenery changes. The reason for having 2 phases is that some participants in this experiment have never experienced VR before, and participants can have a stronger reaction to the virtual environment compared to participants who have VR experience [1]. Therefore, tutorials are used to set the baseline for participants regardless of their experience in VR. To further improve the accuracy of the data, all measurements of the experiment are taken 3 minutes after the start of VR. This is to provide some time for participants to calm down after some exposure instead of feeling awe for reasons other than the virtual environment.

As explained earlier in the report, awe can be described as a mix of multiple emotions, including fear, amusement, and wonder. We can find the feeling of fear and amusement in the study [28]. According to a study, fear affects the following:

- Increase in HR
- Increase in RSA
- Increase in RR

And Amusement affects the following:

- Increase in HR
- Increase in RSA
- Increase in RR

Various other physiological measurements are affected by fear and amusement. However, due to technical limitations, the study will only work around these three measurements.

4.3.2. Subjective measurement

Subjective measurements were taken after the experiment. The participants were asked to fill out a questionnaire rating their emotions and immersion after the experiment. The questionnaires will be in the form of a Likert scale asking the participants to rate from strongly disagree to strongly agree [31]. The Likert scale is one of the most common measurement methods for self-report [32, 33]. The Likert scale provides a convenient way to measure unobservable constructs, detailing the process of the participant's emotions during the time of immersion. However, there is an ongoing debate discussing the Likert scale. At its core, the Likert scale is an ordinal scale, which means it only indicates rank and order. Today, many researchers are using it as an interval scale, which means that there are equal intervals between different points on the scale [42, 43]. This is making parametric statistical methods like t-test or ANOVAs easier to perform on the data. However, some argue that the Likert scale should only be treated as ordinal scale and nonparametric methods should be used, some also claim that treating the Likert scale is a 'sin' of statistical analysis [59].

Despite the ongoing debate, the Likert scale is still widely used in research for many reasons. It is easy to use and interpret for researchers. The interval rating from 1 to 5 is straightforward for researchers to understand and interpret. They offer a direct way of understanding the emotions of the users [31]. They are flexible and can be widely used in research, business, marketing, and education. The flexibility ensures their sustained relevance across different fields [60]. Many existing scales are also using a similar format as Likert and have been validated across multiple studies. Which marks Likert scale as a reliable tool for research.

Participants are required to evaluate 30 statements from the Awe Experience Scale (AWE-S), developed by Chirico and her colleagues [62, 65]. AWE-S is made with a multifactorial design in mind. This allows researchers to conduct experiments with two or more independent variables. The AWE-S development was based on empirical research, ensuring all statements are relevant and directly linked to the study of awe. In the study, Chirico and her colleagues have rigorously tested the validity to ensure its reliability by comparing to multiple existing measurement scales stated as follows: The modified differential emotion scale (mDES) [63], The dispositional positive emotion scale (D-PES) and the big five aspect scale (BFAS) [64]. The study shows that the AWE-S is a stable and reliable 6-factor state measure, which explains the use of questionnaires based on AWE-S.

4.4 Procedures

To ensure that the experiment runs smoothly for all participants. A set plan is followed, this includes explaining the consent form and rules of the experiment, explaining how the experiment will run, following the VU-AMS manual when applying the electrodes and providing support to the participants when needed. An experiment room is made available for this experiment, it was cleared and clean prior the experiment, providing the best possible working environment for the experiment.

5. Results

5.1. Summary of the VU-AMS measurement

Test Description (Variance)	Sample Size	Test Type	Levene's statistic	t-statistic	P(T<=t) two-tail / P-Value	one-tailed p-value	Significant?
HR (Unequal)	10	T-Test	0,31	0,31	0.77	0.38	No
RR (Unequal)	10	T-Test	2,2	1,34	0.21	0.11	No
RSA (Unequal)	10	T-Test	0,83	-1,62	0.13	0.93	No

Average Heart Rate (HR):

Petra_VE	87.065648
Tutorial_VE	87.637278

Average Respiration Rate (RR):

Petra_VE	18.116056
Tutorial_VE	18.873017

Average RSA:

Petra_VE	51.157146
Tutorial_VE	46.401534

5.1.1. Heart Rate (HR)

The initial prediction was that Petra_VE will have higher HR than Tutorial_VE. However, the results show that they are smaller. The average HR for participants in Petra_VE is slightly lower than Tutorial_VE by around 0.57. This subtle decrease is counterintuitive to our expectations.

It is essential to consider that the sample size is only 10 participants, which limits the generalization of the findings. Despite the minor drop, the differences in HR between the two VE are negligible and might not have a meaningful significance. The statical analysis further validates this observation, as the two-tailed p-value of 0.77 and one-tailed p-value of 0.38 indicate no statistically significant difference in HR between the two environments.

5.1.2. Respiratory Rate (RR)

For RR, the data indicate a somewhat larger difference between the two environments than what we have observed for HR. Participants in the Petra VE exhibited a mean RR of 18.116056 bpm, while the Tutorial VE participants exhibited a slightly higher average of 18.873017 bpm. Although Petra_VE was predicted to have a higher value, the observed value suggested a decrease in comparison to the Tutorial_VE. Given the limited sample size, any conclusion drawn from this experiment should be taken with caution. The associated two-tailed p-value of 0.21 and a one-tailed p-value of 0.11 further indicate that the observed differences in RR are not statistically significant.

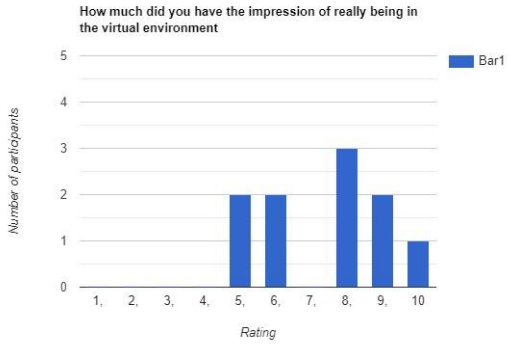
5.1.3. Respiratory Sinus Arrhythmia (RSA)

Analyzing the RSA, the data have shown that Petra VE had an average RSA of 51.157146 msec, which is higher than the Tutorial VE's average of 46.401534 msec. The differences are in line with the prediction of an increase in RSA for Petra. However, the statistical tests show a two-tailed p-value of 0.13 and a one-tailed p-value of 0.93. This suggests that while the difference in RSA might appear notable, it's not statistically significant given the current sample size.

5.2 Summary of the Questionnaires

In appendix 9, describes all the results of the participant's questionnaires in the form of a table. As shown by the table, we can find that the highest average emotion elicited by the participant is Awe with an average rating of 4.1, followed by amusement and joy with an average rating of 3.4. However, fear only scored 2.4, which is one of the lowest scores in the questionnaires. This is opposed to Shiota's description of awe, she described awe as a mix of fear, amusement, wonder, and other various emotions [16]. To understand the reason behind low rating, fear emotion must be understood first. Fear is one of the most important emotions to ensure survival, it helps humans and animals avoid danger, it is described as a survival stimulus that evolved through time [29]. The amount of fear elicited is subjective to the environment and the participants in the environment. Different participants can experience fear at different levels, but we cannot claim that awe is not described by fear and other emotions as the study is small and does not have a strong opposing argument to the study.

For question "How much did you have the impression of really being in the virtual environment?" tries to check the scale of presence and immersion experience by the user with an average score of 7.4, with distribution shown in the figure.



This is a medium-high number in the context of scale. However, to see the effectiveness of presence and immersion. It must be compared to a similar study. A successful study by Slater and his colleagues focused on the Depth of presence in virtual reality [53]. Slater asked the participants three questions: "In the computer-generated world I had a sense of 'being' there"; "There were times during the experience when the computer-generated world became more real or present for me compared to the 'real world'"; "The computer-generated world seems to me to be more like". All these questions scored over 6 out of 7. This shows that this virtual reality experiment has the potential to generate much stronger presence and immersion effect on participants. This does not mean that this study does not create a sense of presence and immersion, but rather not strong enough experience for all participants to experience these senses.

Lastly, looking at the 30 statements of the questionnaires, there are 2 statements scores with an average of 4 or above. 'I tried to understand the magnitude of what I was experiencing.', and 'perceived vastness'. These are followed by 'I felt small compared to everything else', and 'I had the sense of being connected to everything' with a score of 3.8. These questions are related to vastness and immersion, as discussed earlier in the report. Awe is a response that often evokes feelings of vastness and challenges one's understanding of the world [7]. Typically, a score of 4/5 is considered high in many contexts. These scores are considered relatively high to high. However, there are some statements relate to awe that scored relatively low, these include: 'I felt in the presence of greatness' with a score of 2.7. 'I felt my jaw drop' with a score of 2.9. 'I found it hard to comprehend the experience in full' with a score of 2.5. We expect these to be scoring above 3, showing some signs of awe at some moderate level. However, this might be due to the environment being too easy to comprehend, little sample size and/or the presence not as strong as it can get.

6. Discussion

The results from the VU-AMS measurements, although not significant in HR and RR, do suggest some level of alliance with the prediction when looking at the RSA. It is important to note that this experiment has a small sample size, and hence we cannot draw any concrete conclusions based on these results. However, the questionnaire results provide a clearer indication of the awe experience. The higher score for some questions associated with awe, presence, and immersion marked some level of awe-emotion elicitation. Although the measurement of fear and other questions related to awe wasn't as high as predicted based on existing

literature. It is possible that the VE for this experiment is not as fear-inducing as other VEs might.

7. Limitation

The main limitation of this study is the small sample size. This restricts the ability to use statistical tests for the findings. Another restriction is the limited understanding of awe elicitation in VR because awe is such a complex feeling and hard to measure objectively. After all, many emotions may elicit the same physiological measurements as awe. While VU-AMS provided physiological measurements, the same emotion can come in different forms and cannot be solely represented through physiological responses.

8. Future Work

Future studies should consider a larger sample size to have more statistical significance and diverse samples. Different VE could be considered to explore awe elicitation in different situations.

9. Conclusion

This study aimed to benefit the field of psychology and contribute to our understanding of how emotion elicitation works in VR. While the physiological measurements didn't show significant changes between the Tutorial_VE and Petra_VE. The subjective measurements from the questionnaires indicated that there are some levels of awe elicitation. More research needs to be done to understand the relationship between awe and VR, with its effect on human psychology.

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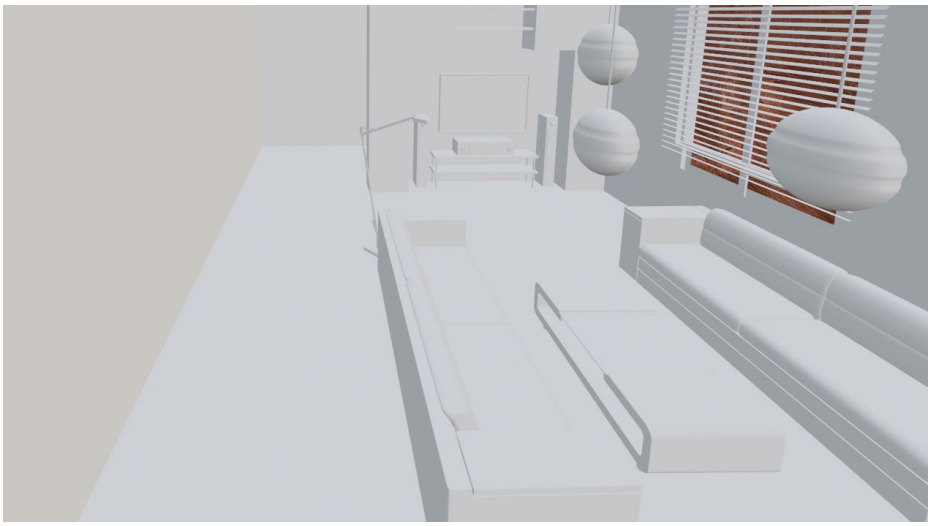
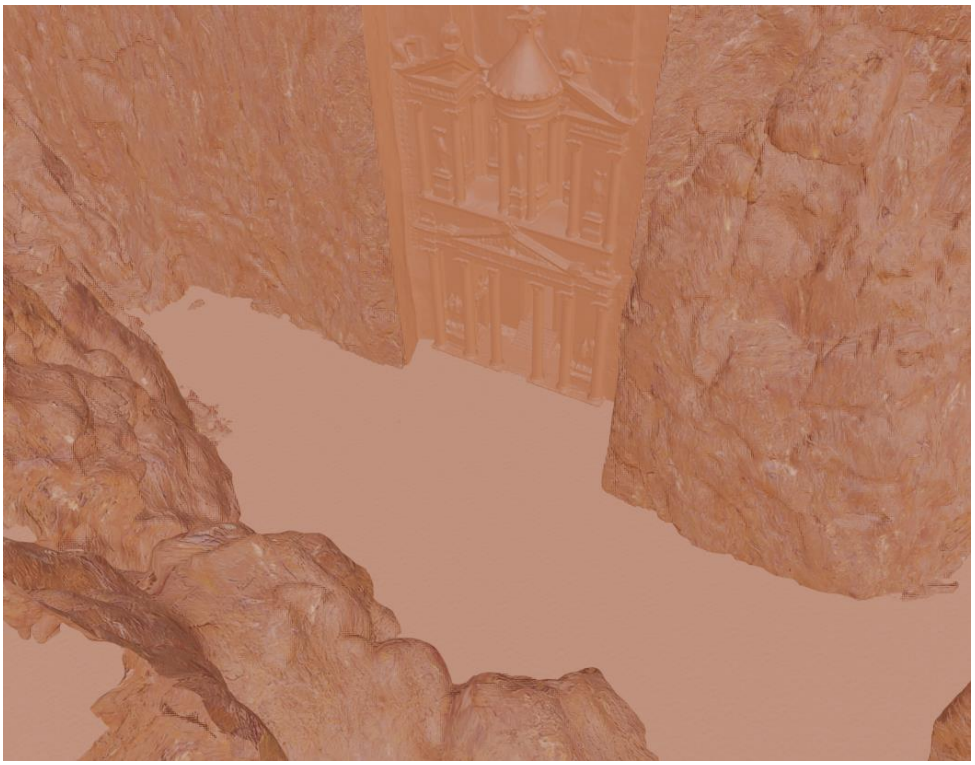
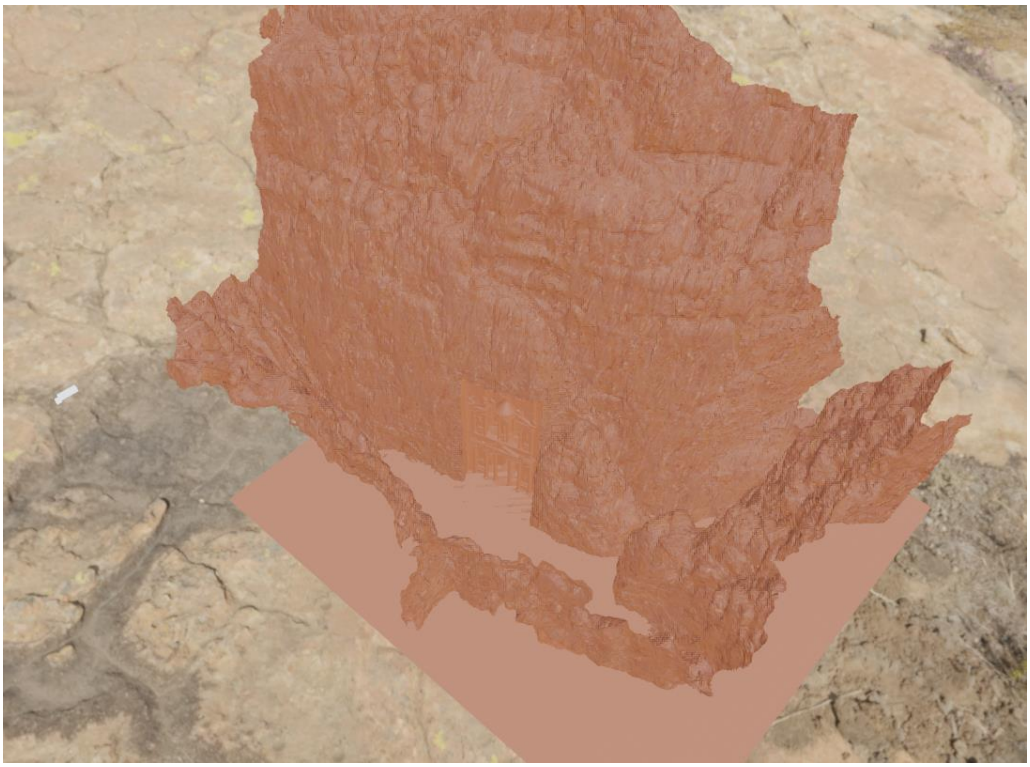
Appendix 1: Tutorial Room

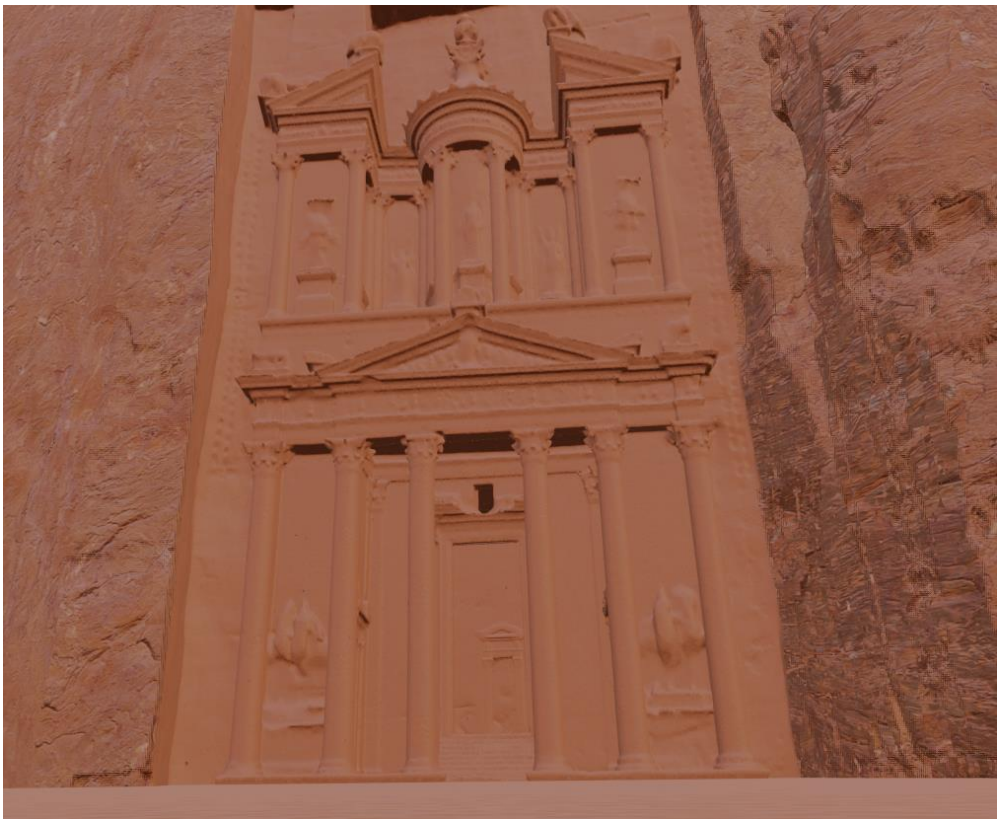


Appendix 2: Petra Canyon

Appendix 3: Petra



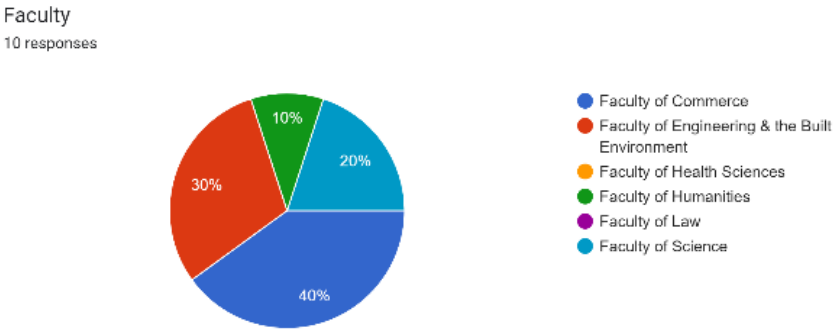




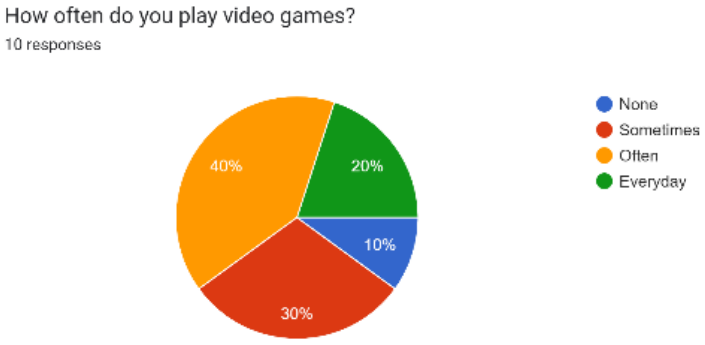
Appendix 4: Risk Assessment Table

Risk Category	Risk Description	Severity	Likelihood	Mitigation Strategy
Technical	Failure to import Blender file to unity	High	Medium	Use different export file type, embedded materials into the file
Technical	Incompatibility between Blender and Unity	High	Low	Maintain most updated version of both software.
Technical	Performances issues such as lag or low frame rate	High	Medium	Decimate the model, cut the model into small piece of the model.
User Experience	VR motion sickness	High	High	Include disclaimers, limit the duration to 15 minutes, allow to stop anytime.
User Experience	Inadequate tutorial or instructions	Medium	Low	Conduct pilot testing on the tutorial and update base on the feedback
Operational	Project timeline delays	High	Medium	Implement agile methodologies for quick iterations and set realistic timeline.
Ethical	User discomfort due to electrode use	Medium	Low	Obtain consent, have participant to choose male or female researcher to apply the electrodes.

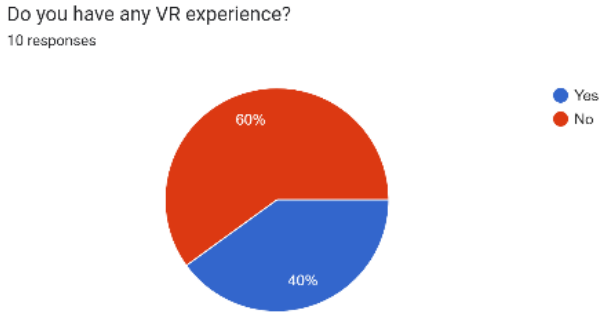
Appendix 5: Faculty?



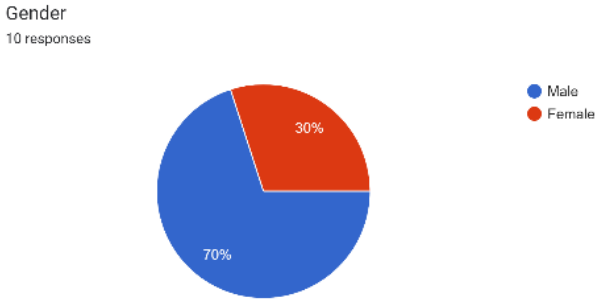
Appendix 6: Video Games?



Appendix 7: VR Experience?



Appendix 8: Gender?



Appendix 9: Subjective Measurement Data

	Participant 1	Participant 2	Participant 3	Participant 4	Participant 5	Participant 6	Participant 7	Participant 8	Participant 9	Participant 10	Average
	Rating out of 10, 1 being Not at all and 10 being extremely										
How much did you have the impression of really being in the virtual environment (1 = not at all; 10 = extremely)?	10	6	9	6	8	5	8	5	8	9	7,4
	Rating out of 5, 1 being Not at all and 5 being extremely										
Anger	1	1	1	1	1	1	1	1	1	1	1
Joy	3	3	5	1	4	3	3	5	4	3	3,4
Sadness	1	1	1	1	1	1	1	1	1	1	1
Pride	5	1	1	1	2	2	1	3	2	1	1,9
Awe	5	4	5	2	5	3	4	5	4	4	4,1
Amusement	5	2	4	2	2	3	5	2	4	5	3,4
Fear	3	1	5	1	4	2	2	1	2	3	2,4
Disgust	1	1	1	1	2	1	1	1	1	1	1,1
	Rating out of 5, 1 being Stongly Disagree and 5 being Strongly Agree										
I sensed things momentarily slow down	1	4	4	1	4	3	3	1	2	4	2,7
I experienced a reduced sense of self	1	3	3	2	5	4	4	1	2	3	2,8
I had chills	1	2	4	1	5	3	3	1	4	2	2,6
I experienced a sense of oneness with all things	4	2	3	3	4	3	4	3	4	4	3,4
I felt that I was in the presence of something grand	5	2	4	2	2	4	3	3	4	5	3,4
I felt that my sense of self was diminished.	1	2	2	1	2	4	3	1	1	3	2
I noticed time slowing	1	2	3	1	4	2	3	2	2	1	2,1
I had the sense of being connected to everything	3	4	4	3	4	4	3	5	4	4	3,8
I felt small compared to everything else	1	5	5	3	4	2	4	5	4	5	3,8
I perceived vastness	4	5	5	4	5	5	4	3	4	3	4,2
I felt challenged to understand the experience	2	2	5	2	2	4	3	1	2	5	2,8
I felt my sense of self shrink	1	2	3	2	2	2	3	1	2	3	2,1
I felt closely connected to humanity	5	2	2	1	2	3	2	4	3	4	2,8
I gasped	3	1	5	1	4	1	5	1	5	4	3
I felt my sense of self become somehow smaller	1	1	3	1	4	2	4	1	2	3	2,2
I had a sense of complete connectedness	4	1	5	1	4	2	3	4	4	3	3,1
I struggled to take in all that I was experiencing at once	1	4	2	3	3	5	2	1	2	2	2,5
I felt my eyes widen	1	2	5	1	4	5	2	4	4	3	3,1
I experienced something greater than myself	4	1	4	1	2	4	2	3	3	3	2,7
I found it hard to comprehend the experience in full	2	1	2	3	4	4	4	1	2	2	2,5
I perceived something that was much larger than me	4	1	4	4	4	2	5	1	2	3	3
I felt my sense of time change	2	1	4	1	4	4	5	1	1	3	2,6
I felt my jaw drop	4	1	5	1	2	2	5	2	3	4	2,9
I felt challenged to mentally process what I was experiencing	1	1	2	1	5	5	1	1	2	5	2,4
I had the sense that moment was lasting longer than usual	1	5	4	3	4	4	5	3	1	5	3,5
I felt in the presence of greatness	3	1	4	1	2	4	2	5	1	4	2,7
I felt a sense of communion with all living things	4	1	1	1	2	4	1	3	2	3	2,2
I had goosebumps	4	1	5	1	2	4	1	5	4	3	3
I experienced the passage of time differently	4	2	4	1	4	5	1	4	1	4	3
I tried to understand the magnitude of what I was experiencing	4	5	4	1	4	4	5	4	5	4	4