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Category	*Min*	*Max*	Chosen
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Theoretical Analysis	*0*	*25*	0
Experiment Design and Execution	*0*	*20*	20
System Development and Implementation	*0*	*20*	10
Results, Findings and Conclusions	*10*	*20*	20
Aim Formulation and Background Work	*10*	*15*	10
Quality of Paper Writing and Presentation	*10*		10
Quality of Deliverables	*10*		10
Overall General Project Evaluation (*this section allowed only with motivation letter from supervisor*)	*0*	*10*	0
Total marks		**80**	

Eliciting the Feeling of Awe in Virtual Reality

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ABSTRACT

Awe is a complex emotion with many elicitors. It is hard to determine the exact aspects that contribute to the feeling of awe in a person, however, this emotion has many positive effects on a person. This project is an experimental design of awe elicitation in Virtual Reality. A fantasy virtual environment was designed to elicit the feeling of awe in the user using various features and elements that were determined as likely awe elicitors. These included supernatural creatures, northern lights and bioluminescence. A user experiment was conducted whereby 10 participants took part and they interacted with both a tutorial environment and fantasy environment. The tutorial environment served as a baseline for both the physiological measurements and the self-report questionnaires. The physiological measurements obtained through biosensors and self-report results were then use to determine the effectiveness of the fantasy environment to elicit awe in the user. The fantasy environment was determined to be successful in the elicitation of awe in the user and was also shown to be more immersive than the tutorial environment. This study can be used as a basis for future research in the elicitation of awe in VR.

1 Introduction

Virtual reality (VR) is a relatively new and continuously expanding technology that makes use of multimodal inputs, which allows users interact with 3-Dimensional content in a manner that resembles real-life interactions (Dozio et al., 2022). Recently, there has been a piqued interest in research regarding using VR to elicit various emotions in people for multiple purposes. VR's immersive ability, as well as its sense of 'Presence', which refers to how realistic a Virtual Reality Environment (VRE) feels to a user when they are interacting with it, has led it to be the primary tool to evoke emotions in a safe, synthetic and controlled environment (Colombo et al., 2021, Diemer et al., 2015, Ke and Yoon, 2020). Training simulations, psycho- and exposure therapy, phobia treatment, human behaviour studies and improving a person's social behaviour and mental health are all different fields that make use of emotion-eliciting VREs (Lipp et al., 2021, Diemer et al., 2015, Susindar et al., 2019, Dozio et al., 2022, Marin-Morales et al., 2020, Colombo et al., 2021). The ability for a VREs to evoke emotions in the user also benefits the entertainment aspect of VR, making the VRE more immersive and realistic, enhancing the user's experience (Susindar et al., 2019).

An emotion that has recently begun gaining traction in emotion elicitation in VR research due to its wide array of positive effects on people is awe (Ke and Yoon, 2020). Awe is a complex emotion that incorporates various emotions and sensations a person feels and pinpointing what causes this emotion to be evoked is difficult to determine (Shiota et al., 2007). Awe is most commonly associated with positive feelings, however, awe can be evoked from negative feelings, an example being feeling fear and dread when witnessing great destruction such as natural disasters (Yaden et al., 2019, Shiota et al., 2007, Pearce et al., 2017). Astonishment, wonder, surprise and connectedness are common, positive feelings that are associated with awe (Chirico et al., 2018, Ke and Yoon, 2020). The most distinguished characterization of awe is vastness and the need for accommodation with regards to expanding one's frame of reference (Shiota et al., 2007). Vastness has many implications including great expanses, encountering something that is difficult to comprehend and experiencing something greater than one's self (Shiota et al., 2007). Some of the positive effects that awe can have on people that has led to its rise in popularity in this research field include increasing a person's satisfaction with life, altering a person's perspective and worldview, influencing people's beliefs as it drives people toward spirituality, protecting a person's immune system, decreasing a person's aggressive nature as well as igniting a drive in people to explore more of the world (Ke and Yoon, 2020, Quesnel and Riecke, 2018, Chirico et al., 2018, Chirico et al., 2016, Nelson-Coffey et al., 2019). The use of awe-elicitation in VR can bring these and other benefits closer to people who may struggle with finance and mobility or people who simply seldom experience awe as a VR device is portable, cheaper than travel and does not need a lot of physical ability to use (Quesnel and Riecke, 2018). Virtual Reality's enhanced features that can create realistic or fictional 3D environments, stimulate emotions and multiple senses and the sense of Presence it evokes in a person makes it the best tool to replicate this emotion in an artificial environment (Quesnel and Riecke, 2018, Chirico et al., 2018).

This project aimed to design an effective awe-eliciting environment due to its relatively unexplored territories and lack of implementation in VR applications and the potential benefits it may provide. A fantasy virtual environment was designed to elicit awe in users which can potentially be used as a basis for future designs of awe-eliciting applications.

2 Related Work

2.1 Considerations for eliciting and measuring awe

2.1.1 What elicits awe

Due to awe's complex nature, determining awe-elicitors is difficult since each person experiences awe differently and different things can evoke awe in different people. However, some key aspects and settings that elicit awe has been uncovered from research. Nature has been shown to be the main awe elicitor which could be due to its wide availability and ease of access (Pearce et al., 2017). Nature is vast due to the wide range of wildlife and plants that it incorporates, providing a seemingly unlimited potential for awe-elicitation. Aesthetic environments, the universe, marine life, natural phenomena, high mountain peaks, waterfalls, dinosaurs, fauna and flora and vast geological expanses all fall under the category of nature and are all prime awe-elicitors (Nelson-Coffey et al., 2019, Dozio et al., 2022, Quesnel and Riecke, 2018, Pearce et al., 2017, Shiota et al., 2007, Ke and Yoon, 2020, Chirico et al., 2018). Spiritual awakening, fireworks, supernatural phenomena and creatures, intricate details and theories, as well as witnessing enigmatic displays of art such as music, sculptures and theatre performances are other sources of awe-elicitation (Quesnel and Riecke, 2018, Pearce et al., 2017, Chirico et al., 2018, Nelson-Coffey et al., 2019, Ke and Yoon, 2020). The various ways to combine and use these features to elicit awe appears endless, exhibiting the difficulty of defining exact methods and features to include in order to create an environment to elicit awe.

2.1.2 How to measure and assess the feeling of awe

Even though there is a shortage of research regarding how to effectively elicit awe in VR, methods and resources have been proposed as useful indicators to identify awe-elicitation in people. Physical reactions that are indicators of a person feeling awe include parted lips, wide eyes, goosebumps and mental freezing (Yaden et al., 2019). Some studies have suggested that females experience goosebumps more often than males which could indicate that females are more prone to feeling awe compared to males, however, other research has shown there to be no difference in the occurrence of goosebumps between the two genders (Quesnel and Riecke, 2018). The implication that females are more susceptible to goosebumps than males could possibly ascertain to the probable notion that males are less likely to report this incidence (Quesnel and Riecke, 2018). Research has also revealed that when people feel awe, their parasympathetic nervous system and EEG brainwaves are both activated (Quesnel and Riecke, 2018). Biosensors, such as cameras that detect facial expressions, heart rate recorders, goosebump cameras and surface electromyography instruments, can be used to detect this (Quesnel and Riecke, 2018). Lengthened pre-ejection period (PEP) and decreased respiratory sinus arrythmia (RSA) are shown to be associated with the feeling of awe (Bernstein, 2022). These physiological changes are both consistent with a lowered sympathetic nervous system activity (SNS) and increased parasympathetic nervous system activity (Bernstein, 2022). T-wave amplitude is an indicator for SNS activity with a lower amplitude indicating higher SNS activity and a higher amplitude indicating lower SNS activity (Nederend et al., 2016). Another physiological indicator of awe is slower heart rate (Bernstein, 2022). Self-report methods such as interviews and numerous types of questionnaires can also be used to identify awe in participants where they verbally or narratively express the emotions they felt (Quesnel and Riecke, 2018). However, because awe is a complex feeling, it may be difficult to express the sensation in words, inferring that interviews may not be as useful compared to surveys that can provide phrases that are typically associated with awe to attain a better understanding of how the participant was feeling (Quesnel and Riecke, 2018). Self-reports can be flawed as participants may provide responses that they believe are expected or responses that may be ambiguous (Quesnel and Riecke, 2018). Research that included biosensors and self-report were shown to improve the findings of the research compared to results obtained in research where only from self-report methods were used.

2.2 How to design a VR environment to successfully elicit awe

There is relatively little methodology available regarding the design and implementation of features in a VE that will successfully elicit awe in the user (Ke and Yoon, 2020). Six strategies were supplied by Ke and Joon (2020) which described methods to create successful awe-eliciting VR environments. These strategies are characterised by fleeting beauty, timeless designs, encountering something that suggests the existence of a higher power, extremely intricate concrete or abstract designs and the impression of interaction with many people striving for the same goal (Ke and Yoon, 2020). All of these tactics play on the two defining characteristics of awe: the need for accommodation by expanding one's frame of reference and vastness (Ke and Yoon, 2020). The ability of virtual reality to provide users with a sense of 'Presence' aids in both a stronger evocation of awe and the degree to which the VRE stimulate the user's senses (Chirico et al., 2018, Pearce et al., 2017). Awe is more likely to be aroused in someone when they see a setting as being more realistic. Therefore, it is crucial that an environment be created that gives the user a realistic look and feel.

2.3 Limitations of current literature

Some design methods for evoking awe have been discovered, but the methodology and features to include when designing virtual environments to implement these strategies and create an effective awe-eliciting environment is still unclear, and there are no standards provided to guarantee that the desired emotion is elicited. Despite the fact that the inclusion and alteration of various noises, colours, objects, textures and interactions has been identified as ways to evoke awe in virtual reality environments, specific methodology on what features to add and what changes should be made to them to achieve this has yet to be clearly defined. Using biosensors to accurately measure the elicitation of awe in participants is also lacking in research as awe is experienced differently by each person and physiological measurements may change in accordance with the person being subjected to awe-elicitors. Common identified bodily responses to experiencing awe have also not been readily used in research to measure the effectiveness of a VR environment in evoking awe in the participants. Wide eyes, a hanging jaw, physical and mental freezing have been identified as common indicators people display when experiencing awe, and studies on virtual reality to evoke awe have yet to use biosensors, such as facial recognition tools, to

identify these changes and use the results to measure the successfulness of the awe-eliciting VR environment.

3 System Development and Implementation

Two VREs were designed, a tutorial environment that also posed as a control environment to provide physiological and emotional baseline data and a fantasy environment that was designed to be awe eliciting.

3.1 Overview of System features

3.1.1 Control vs Awe-eliciting environment

The control environment was simply designed as a room with four walls and no roof that also served as a tutorial. This design was chosen as the player simply needed to learn how to navigate in a VRE using the controls, as well as to make the environment as bland and not awe eliciting as possible to be used as a baseline for their biosensor stats and questionnaire results. The awe-eliciting environment was designed as a fantasy world to evoke awe and had various features and elements that were absent from the control environment to evoke awe. Fantasy was the decided theme to evoke awe as it could incorporate a wide array of features that one could not experience in real-life and indicated great potential to effectively elicit awe.

3.1.2 Awe-eliciting fantasy environment

The supernatural and natural phenomena were identified as likely elicitors of awe. This inspired the idea of a fantasy environment to be designed where the user could step into a world which is completely fictional and one they could never experience in real life. The immersive ability and sense of 'Presence' VR provides allows this seemingly impossible environment to feel completely real to the user, increasing its chances of evoking awe from features that many would find difficult to grasp due to its supernatural nature. The primary features chosen to elicit awe included the northern lights, dragons and bioluminescence. The bioluminescence was ascertained through a glowing waterfall, a bioluminescent rhinoceros as well as glowing rocks and mushrooms. A fantasy audio was also included in the VRE to enhance the mystical feel of the fantasy world the users explored.

3.2 Requirements gathering and analysis

Weekly meetings were implemented with my group and supervisor to discuss the requirements of the project as well as to check our projects' progress and receive feedback on changes that could be made and solutions to issues that were encountered. A literature review was done at the start of the project to analyse what research has been done, uncover what elicits awe and obtain ideas on how to create an awe-eliciting environment. This research also provided quantitative and qualitative methods on how to assess the effectiveness of the VRE to evoke awe in participants through use of various biosensors and self-report. As a group, we discussed what elicits awe and each decided on using various techniques and awe-elicitors that incorporate different types of vastness to design unique VREs to elicit awe. One member designed a replication of Petra in Jordan that incorporated vastness through extremely tall rock surfaces and intricate details on the stone surfaces. Another member designed a mountain range designed after the Huashan mountains in China. This incorporated vastness through wide expanses, where the world seemed endless, making the participant feel small in comparison. The fantasy environment I created incorporated vastness and need for accommodation through its supernaturality and complex ideas of how such mythical creatures and natural phenomena could occur. The beauty of the plants, creatures and natural phenomena was unique, some were simply not commonly experienced, and the environment was one that people could not see in the real world.

3.3 Design Approach

The first step in the design of the environment was an experimental design, whereby a rough sketch was drawn, representing the idea for how the environment would be mapped out and what features would be included. This was shown to our supervisor who gave us feedback on what we were planning to create so that we can adjust the design accordingly, ensuring that the assets we were thinking of using would be easily accessible and that the scope of our design was attainable. The second step in the design process was to find available assets from unity and other free online sources that would be used in the VRE, testing which assets functioned appropriately in unity and adjusting the design of the environment to incorporate the assets that were chosen.

An agile design approach was chosen for the development of the project to complete small portions of the work and test if it works, and make any changes before adding new features to the environment. The first iteration of the project was to get started in Unity by designing a simple layout of the environment and including one of the primary awe-elicitors, the dragon, to ensure that it worked before adding more elements to the environment. The terrain and mountains that were used in the background were also included in this iteration. The dragon was a free 3D asset accessed online and was found to have an error in unity after transferring it from blender whereby the wings disappeared from certain angles. This error could not be resolved and it was decided that I would position the dragon in such a way that the user would not be able to see this glitch. The second iteration of the project included adding trees, the northern lights, a pond and a bioluminescent waterfall to the environment. When testing it on the laptop all appeared to work well, however, when testing it using the VR headset, the pond turned purple and the northern lights were only visible through one eye. This problem was solved by changing the rendering settings of the VR environment. The third iteration included adding another dragon that would fly above the user and adding animation to the object to allow it to do so as well as adding a bioluminescent rhinoceros and a faerie. The dragon was found to fly too fast and so the animation was adjusted and the actions of the faerie and rhinoceros did not loop and so the settings were changed to loop the animations of these assets. The following iterations were repetitions of the previous iterations, adding more game objects to the environment and testing that it worked and trying to

fix what did not or removing faulty assets until the final design was accomplished. The final design included the addition of a blue fire surrounded by glowing rocks, floating pots at the beginning of the path, totems, rune pillars and glowing mushrooms and flowers.

3.4 Quality checks during development

The quality of the project was maintained by ensuring that all assets added to the environment did not hinder the functionality of other assets and that the program still operated optimally when added. When compile errors occurred, the asset was either removed from the project or the error was fixed to allow the environment to run smoothly. The quality of the actual asset was also assessed to ensure that it was of a high enough standard and did not appear fake or unappealing to the eye. The asset was also checked to ensure that it fit in well with the other game objects to ensure that the environment appeared seamless and not mismatched. Some objects were placed in separate areas to maintain this seamless appearance when objects looked mismatched. The frame rate of the virtual environment was constantly checked to ensure that the user moved at an optimal speed and the environment did not appear to be lagging. The addition of many trees in the environment proved to use too much computational power, causing the VR headset to lag tremendously and so trees were added as a border around the path and pond, just enough that the users could not see beyond them.

3.5 Testing

The environment was tested by running the Virtual Reality Environment using the VR headset. This was to check what errors occurred when moving the files to a new computer as well as to ensure that the objects appeared and worked as they should when immersed in VR. Unnecessary assets that were downloaded were removed to decrease the file size and transfer time between machines. Assets could be redownloaded on any machine from the asset store if needed. The environment was repeatedly explored using the VR headset after additions and alterations were made to check that everything functioned properly to ensure a smooth working environment for the experiment. Missing assets or changes not apparent after transferring the files were fixed on the computer being used and saved. My two Honours teammates and a UCT student from a different faculty tested the VRE where they explored the environment in order to provide feedback. They were all aware of the nature of the VE and provided feedback on areas that could be improved or changed and the how effective they believed the environment to be to elicit awe. They also pointed out any errors in the VRE that I might have missed that needed to be fixed. This determined the tasks to be carried out in the following iteration of the design of the environment.

4 Experiment Design and Execution

4.1 Participants

10 UCT participants took part in the experiment with a mean age of 21.3. A small number of participants took part as this project was decidedly an experimental study to further future research and projects in this respect. UCT students were chosen as the participants as they are easier to recruit. Participants were warned of possible motion sickness due to taking part in the VR experiment and were advised not to partake if they were prone to this illness. On a scale of 1-5, the participants each rated how often they play video and computer games and also how often they have used VR. The average frequency of playing video games was 3.3 with a standard deviation of 1.55 and the average frequency of using VR was 1.5 with a standard deviation of 0.92. It was also apparent that the male participants had a lot more gaming experience than most of the female participants with their average alone being 4.6 and the females average being 2.

4.2 Ethical Considerations

Ethics regulations are of the utmost importance in user experiments such as this, as Virtual Reality can induce motion sickness and electrodes are needed to be applied to the participants upper body to obtain physiological results. We applied for ethics clearance from the Psychology Department at UCT where we explained the nature of our experiment and what it entailed, detailing the possible ethical risks it involved and how we planned to alleviate them. One ethical concern was that the true intent of the experiment had to remain unknown to the user to ensure the integrity of the experiment and receive honest answers in the self-report questionnaires. This was crucial to the experiment in order to remove the risk of subject bias, also known as the Hawthorne effect, which describes the nature of participants to alter their answers and behavioural manners in a study according to what they believe the researchers want or expect (Nguyen et al., 2018). Although we could not disclose at the beginning of the experiment what the aim was, we simply stated that we were testing for an emotional response to the environment and at the end, the true intent that we were testing for an awe response was made known. Since the risk of negative effects was minimal with regards to the nature of our project, and participants who experience distress or motion sickness could end the experiment at any time, this deception was allowed. Other ethical concerns included the risk of motion sickness and consent to applying electrodes to the upper body of the participants. These ethical concerns were alleviated by making the participants aware of the procedure and risk of motion sickness by partaking in the experiment. If the user felt motion sickness or wanted to end the experiment at any time during the experiment, they were allowed to without question and their data was discarded. Applying the electrodes onto the upper body of the participants was also an ethical concern as it would be unethical for males to apply the electrodes to females and vice versa. This concern was alleviated by ensuring the participants were comfortable with having the electrodes applied to their body and by having a male to apply the electrodes to male participants as well as having a female to apply the electrodes to female participants. The participants also signed a consent form agreeing to this procedure before the experiment begun.

4.3 Measurement

Quantitative measurements were obtained through the means of physiological measurements as well as Likert scale questionnaires. The physiological measurements included ECG and ICG readings which measured the heart rate and rhythm and the electrical conductivity such as blood flow. These measurements were included to observe differences in the participants' body response to the control and awe-eliciting environment. Slower heart rate and respiration rate, lengthened PEP and decreased RSA are indicators of awe. Through the use of biosensors measuring the ECG and ICG of participants, these measurements are able to be attained and can be compared during the time of the tutorial, which serves as the baseline measurements, with the measurements acquired at the time the participants were in the awe-eliciting fantasy environment. The data attained from the biosensors can be used to test for any significant differences between the control and awe-eliciting environments to ascertain whether an awe response was achieved in accordance with the changes in the physiological measurements that have been identified to indicate the feeling of awe. The self-report questionnaires consisted of a basic presence questionnaire (BPQ), an emotion questionnaire and an AWE-Experience Scale questionnaire. The questionnaires were used to identify the difference of participants' experiences in the control and awe-eliciting environment to identify different levels of immersion, emotional response and awe experience between the two environments. The BPQ was a one question survey where the participant had to rate on a scale of one to ten how real the environment felt to them, with ten being very realistic. This was an important question as the more real the environment appears to the participant, the greater its chances are of evoking awe and other emotions in the user. If the environment did not appear real to the participant, it would have been unlikely for the environment to have evoked an awe response in the participant. This questionnaire was answered after both the tutorial and fantasy VREs to help analyse the results. A five-point Likert scale was used to evaluate the emotional state of the participant. The participants had to rate the extent to which they felt anger, joy, sadness, pride, awe, amusement, fear and disgust on a scale from not at all to extremely. This allowed to test the degree of these emotions that each environment evoked and how these emotions changed between the environments. Assessing all of these emotions were important in that it could ascertain to why certain physiological results were recorded and how it may have affected awe elicitation. This questionnaire was also done after both the tutorial and awe-eliciting fantasy environment in order to analyse any change in emotional state between the two VREs. The Awe-Experience Scale was the primary self-report questionnaire to truly grasp the extent to which participants felt awe in each environment and how it changed between environments. The Awe Experience Scale (AWE-S) was designed to assist in the identification of this complex emotion by creating sentences that relate to possible feelings a person may associate with awe (Yaden et al., 2018). Six primary factors associated with awe were identified in the study to create the AWE-S, namely self-diminishment, change in the perception of time, vastness, need for accommodation, physical sensations and the feeling of connectedness, which formed the basis of the AWE-S with each sentence describing one of these factors (Yaden et al., 2018). The participants rated the degree to which they agreed with each feeling described in the AWE-S, with one being strongly disagree and five being strongly agree, and the cumulative score indicating the degree to which they felt awe with a higher score indicating a stronger feeling of awe. This questionnaire was done after the tutorial environment and after the fantasy environment to determine any change in the degree of awe the participant felt between environments.

4.4 Procedure

The procedure of the user experiments began with setting up the VR headset, tutorial environment and VU-AMS before the participant arrived. Once the participant arrived, an explanation was provided regarding what the experiment entailed followed by having the participants sign a consent form, agreeing to partake in the experiment, acknowledging that they understand the proceedings of the experiment and the potential risks of partaking in the experiment. After this, the electrodes were then applied to the participant and the measurements were then checked to ensure that the readings were correct. Electrodes were adjusted to improve the VU-AMS readings if needed. Once the VU-AMS was satisfactorily set up, the participant was immersed into the tutorial, control, environment using the VR headset where they learned how to use the controls and a baseline was obtained for the physiological measurements. Once the user was comfortable navigating the tutorial with the controls, they were taken out of the environment and the headset was removed where they then proceeded to answer the BPQ, emotional state and AWE-S questionnaires. Once the questionnaires were completed, the participant was immersed into the fantasy, awe-eliciting, environment where they were able to explore VRE for five to ten minutes, taking in the various aspects of the environment. Once that was done, the VR headset was removed and the participants answered the same questionnaires. At the end of the experiment, the electrodes were removed and the VU-AMS data was saved. The participants were thanked for their time and received their compensation for partaking in the experiment and signed to confirm that they had receive their compensation.

4.5 Data Management and statistical analysis

The self-report data was analysed through use of t-tests, namely identifying if there were any significant differences in the answers provided for the tutorial and fantasy VREs. P-values less than 0.05 indicated that there was a significant difference. This allowed for the participants' emotional state, sense of 'Presence' in the VREs and degree to which they felt awe to be analysed to determine the effectiveness the fantasy environment had in eliciting awe in the participant. T-tests were also used to analyse potential differences in the physiological data obtained from the tutorial and control environment. If significant differences were obtained from the measurements that were likely to be affected when feeling awe, such as heart rate, the data was analysed to see if these changes corresponded to the identified physiological indicators of awe.

5 Results and Discussions

This section supplies the results of the physiological and self-report data. Significant and important results are outlined and discussed below. All of the data is normally distributed, enhancing the validity of the results.

5.1 Summary of physiological results

Table 1: Summary of Physiological significance

Type of measurement	p-value (one-tail)	p-value (two-tail)	Significance
Heart rate	0.009438334	0.018876669	YES
Respiration Rate	0.443711038	0.887422076	NO
Pre-ejection Period	0.401218654	0.802437308	NO
Respiratory Sinus Arrythmia	0.460290058	0.920580117	NO
T-wave amplitude	0.020618896	0.041237791	YES

Above is a summary of the t-tests performed on the physiological measurements that are indicators of awe and their significance.

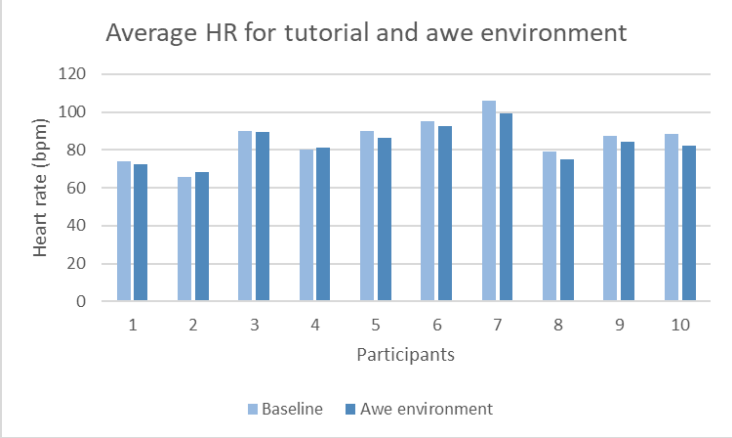

Figure 1: Average heart rate for the tutorial and awe environments

The average heart rate for the tutorial, baseline, environment can be seen to be higher than that of the fantasy, awe environment (Figure 1). Although some participants experienced an increased heart rate in the fantasy environment compared to the tutorial environment, there was a significant change in average heart rate between the two environments, indicated by the p-value of 0.019. The decrease in HR experienced in the awe environment is associated with the feeling of awe.

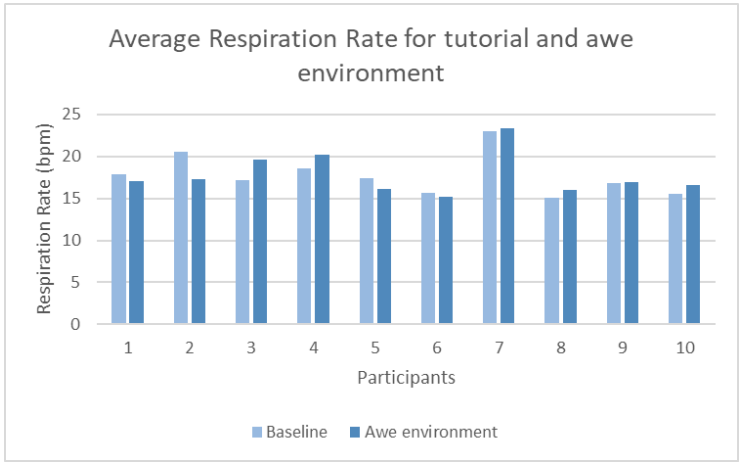

Figure 2: Average Respiration Rate for the tutorial and awe environments

There is no apparent trend in the change of respiration rates between the two environments. Some people experienced an increased respiration rate in the awe environment while others' respiration rate decreased in the awe environment. The p-value obtained through the t-tests indicate no significant changes in respiration between the two environments. Awe is associated with a slower respiration rate which is not apparent in these results.

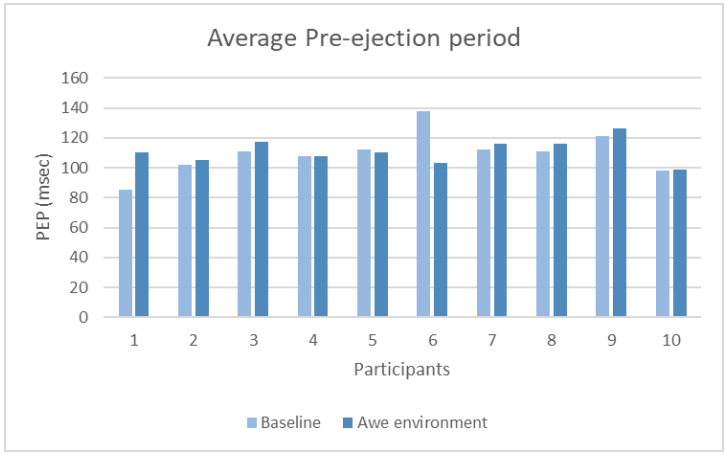

Figure 3: Average PEP for the tutorial and awe environments

The PEP does show an increasing trend where the PEP is lengthened in the awe environment compared to tutorial environment in most participants but some participants do experience a decrease in PEP in the awe environment. The t-test indicates an insignificant p-value. However, participant 6 experienced an extreme decrease in PEP compared to the other participants. Removing this participant from the t-test provides a significant p-value when computing a one tail t-test which provides a p-value of 0.04. Awe is associated with a lengthened PEP, and with the exclusion of participant 6, the results conform to this.

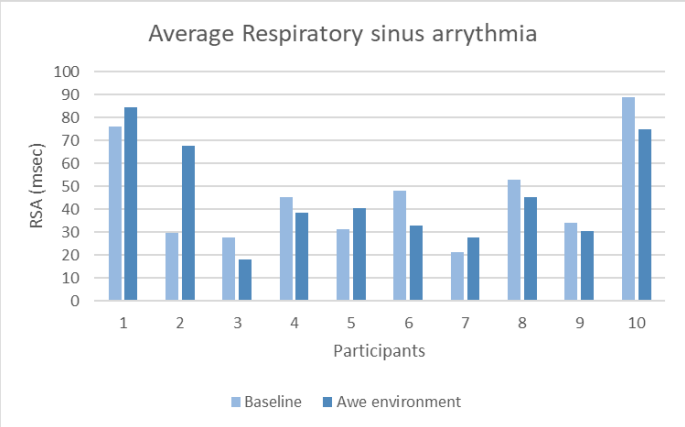

Figure 4: Average RSA for the tutorial and awe environments

As with the RR, there is no apparent trend found in the results with no significant difference between the average RSA experienced in the tutorial and awe environments as indicated by the p-value. Awe is associated with decreased RSA and although some participants did experience this, the results are too variable to draw any significant conclusion from the data.

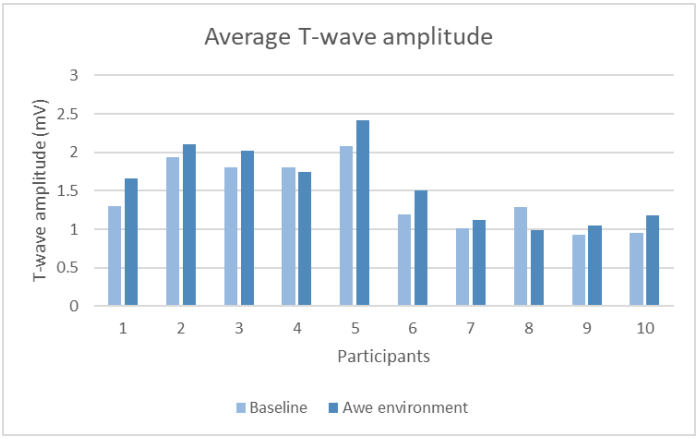

Figure 5: Average T-wave amplitude for the tutorial and awe environments

There is a general increasing trend between the two environments where the T-wave amplitude is greater in the awe environment compared to the tutorial environment. A p-value of 0.04 indicates the significance of the change in T-wave amplitude between the two environments. Greater T-wave amplitudes is associated with lower SNS activity which in turn is an indicator of awe.

5.2 Summary of self-report results

Table 2: Summary of emotional state changes between tutorial and awe environments

Emotion	p-value (one-tail)	p-value (two-tail)	Significance
Anger	N/A	N/A	NO
Joy	0.000333808	0.000667617	YES
Sadness	0.171718198	0.343436396	NO
Pride	0.001620607	0.003241215	YES
Awe	0.001931949	0.003863898	YES
Amusement	0.011449747	0.022899495	YES
Fear	0.5	1	NO
Disgust	N/A	N/A	NO

Table 3: Summary of Questionnaire t-tests

Questionnaire	p-value (one-tail)	p-value (two-tail)	Significance
Basic Presence Questionnaire	9.6179E-05	0.000192358	YES
Awe Experience Scale	3.53526E-05	7.07052E-05	YES

Table 2 represents the significance of changes for the various emotions that participants felt between the tutorial and awe environment. Table 3 represents the significance of difference of the BPQ and AWE-S questionnaires between the two environments.

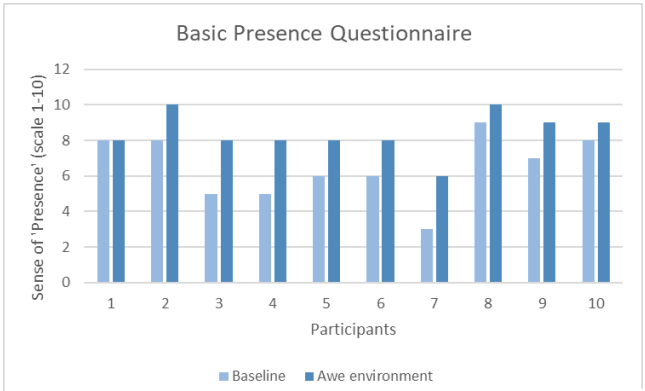

Figure 6: BPQ scores for tutorial and awe environments

There is a clear increasing trend from the sense of 'Presence' experienced in the tutorial environment to that experienced in the awe environment. A p-value of 0.0002 indicates the significance of the difference between the scores obtained from the tutorial and fantasy environments.

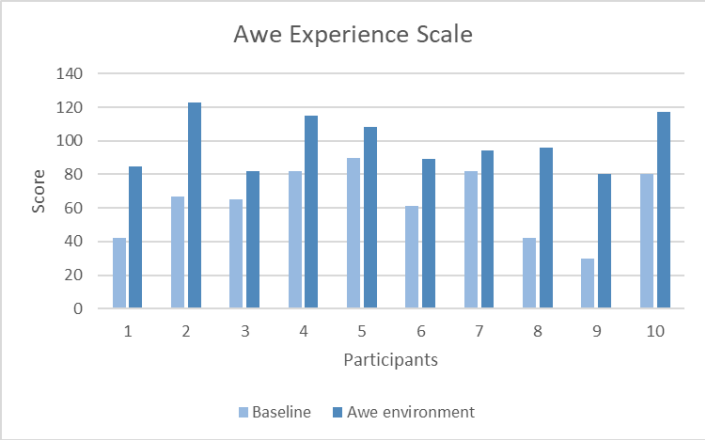

Figure 7: AWE-S scores for the tutorial and awe environments

As in figure 6, figure 7 displays a distinct increase in scores, increasing from the tutorial environment to the awe environment. A p-value of 7.07052E-05 indicates the significance of the difference between the scores obtained the control environment and that obtained from the fantasy environment. Two further t-tests were done to identify if there was a significant change in the scores for the feeling of "I had chills" and "I had goosebumps" between the two environments. The p-results were 0.003 and 0.008 respectively, indicating that there were significant changes. There was an increasing trend for both of these feelings from the tutorial environment to the fantasy environment. The total scores for the AWE-S questionnaire were used to implement one-tail t-tests to compare if there was any significant difference for the participants who had a lot of gaming and VR experience and those who did not. The p-value for the tutorial environment was 0.13 and the p-value for the fantasy environment was 0.27, indicating no significant difference in the results.

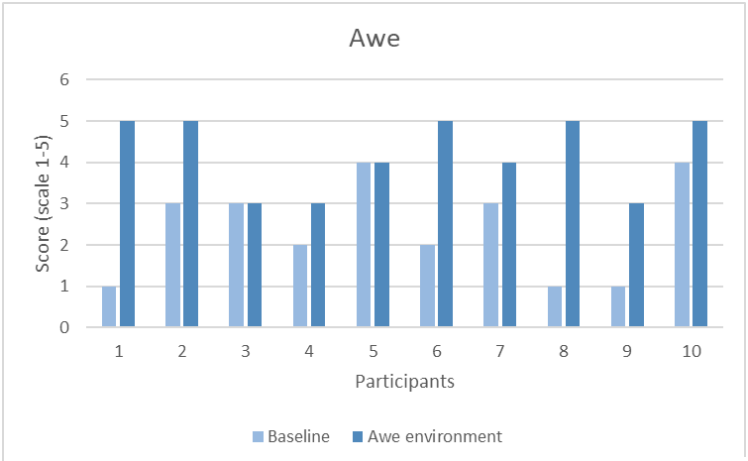

Figure 8: Awe scores from the emotion's questionnaire

There is a clear increasing trend of awe experience from the tutorial environment to the fantasy environment. A p-value of 0.004 indicates a significant difference in the scores between the tutorial and fantasy environment.

5.3 Discussion of results

Certain physiological data indicated that participants experienced awe, namely the heart rate and T-wave amplitude. Studies showed that the slowing down of heart rate is an indication that the feeling of awe is being felt. While two of the participants had an increased heart rate in the fantasy environment compared to the tutorial environment, majority of the participants experienced the inverse of this. With a significant p-value, these results indicate that the participants felt an increased sense of awe in the fantasy environment compared to the tutorial environment. T-wave amplitude is a physiological measurement that is associated with SNS activity. SNS activity increases when the T-wave amplitude decreases and SNS activity decreases when T-wave amplitude increases. Lower SNS activity is an indicator of awe. The results showed that there was a significant difference between the T-wave amplitude recorded in the tutorial environments and that recorded in the fantasy environments. The T-wave amplitude showed an increasing trend from the tutorial to fantasy environment. The increase in T-wave amplitude implies that the SNS activity decreased from the tutorial environment to the fantasy environment. Therefore, this decrease in SNS activity is an indication that awe was evoked in the fantasy environment. Although the other physiological results did not exhibit any significant changes, it is better than having significant change in physiological results that contradict the changes in these measurements that indicate awe, such as an increased respiration rate when awe is associated with a decreased respiration rate. The PEP did have one outlier, which when removed, provided a significant p-value. This could be another indicator that awe was evoked in the fantasy environment compared to the tutorial environment.

The self-report questionnaires provided clear evidence that awe was evoked in the fantasy environment. The scores recorded from the AWE-S questionnaire had a distinct increase from the tutorial environment's scores, indicating a greater sense of awe was experienced by all participants in the fantasy environment compared to the control environment. This is further supported by the significant increase in the score for awe from the emotional state questionnaire. The BPQ also indicated that the participants felt the fantasy environment to be more realistic than the tutorial. This could be due to the complexity and greater interaction of the fantasy environment, alluding to its success in the elicitation of awe as the more real an environment feels to the user, the more effective it is in emotion evocation. In the AWE-S questionnaire, two of the feelings described included "I had chills" and "I had goosebumps". These two physical sensations are closely associated with awe and the p-values indicate that the results were significant. The increase in scores of these sensations from the tutorial environment to the fantasy environment further support that awe was elicited in the participants. Gaming and VR experience also did not have any

effect on the elicitation of awe in the user with t-tests calculated on both the AWE-S questionnaire scores for the tutorial and fantasy environment. Both p-values implied that there were no significant differences in AWE-S questionnaire scores for participants who had a lot of experience in gaming and VR compared to those who did not.

6 Conclusions and Future Work

Although some people may argue that simply immersing into Virtual Reality can elicit awe, this experiment has clearly demonstrated that designing a VRE that includes awe-elicitors and provides a greater sense of 'Presence' increases the effectiveness of the VE to evoke awe. The fantasy environment that incorporated the supernatural, natural phenomena and bioluminescence as well as mystical music was successful in eliciting awe in the participants, making this study a success. This study can be used as a basis for future research and applications in eliciting awe in Virtual Reality. It can be improved in the future by doing more thorough user experiments, incorporating more people and using biosensors tailored specifically for identifying awe characteristics such as wide eyes, dropped jaws and goosebumps. This study also provides awe elicitors that were successful in evoking awe in the users and can be reused and expanded upon in future work. Future work can also stimulate more of the senses to investigate how this influences the successfulness of VR to elicit awe in users. It can also research into how different degrees to which awe is experienced by the user affect the positive effects that awe has on people.

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Appendix 1: Pictures of the final fantasy VRE