VREmote

The Effect of User Control on Eliciting Sadness and Fear in Virtual Reality

Iain Hutcheson
Department of Computer Science
University of Cape Town
Cape Town, South Africa
HTCIA001@myuct.ac.za

Julia Kinghorn
Department of Computer Science
University of Cape Town
Cape Town, South Africa
KNGJUL010@myuct.ac.za

1. Project Description

Emotions often dictate human behaviour, and it is important to understand how to elicit them in a controlled environment so their effects on individuals can be studied further [1]. Virtual Reality (VR) is a technological medium that allows for real-time interaction with synthetic stimuli, where users can be immersed in a computer-generated 3D environment [2]. It has been used increasingly in research on emotion elicitation because of its ability to transport patients beyond spatial and resource constraints. Many argue VR's degree of immersion presents a more reliable method for elicitation of emotion than less immersive displays, such as film and photographs. Additionally, because researchers have full control over a Virtual Environment (VE) and can modify its conditions when necessary, VR is useful as a relatively safe and accessible medium to elicit emotions that are considered harmful [3, 4, 5]. At present, the most effective method of emotion elicitation using VR still needs to be determined. The effect of factors such as presence and immersion have been investigated extensively. Presence can be described roughly as the level of involvement a user feels with the simulated scenario, despite its artificial nature [7]. Immersion refers to what technology objectively delivers in terms of the sensory displays it affords. However, the effect of a VR system's interactivity on emotion elicitation has not been explored, despite possible major significance. Thus, we plan to determine how user control effects the elicitation of Sadness and Fear in VR.

We focus on Sadness and Fear because human experience of these emotions is ubiquitous, but our understanding of them is limited. While they can be recognised with well-developed self-report techniques and psychophysiological measurements, little is understood about how user interaction affects their elicitation in VR. Given their role in human behaviour – sadness in facilitating social attachment and empathy, and fear in self-protection responses - finding a reliable elicitation of both would be invaluable.

2. Related Work

Throughout the literature, we have tried to identify the best methods for eliciting and measuring Fear and Sadness in VR. The vast majority of research is concerned with the effect of presence, a separate psychological phenomenon, on emotion elicitation, but provides good methodological insight. Further limitations in current research have also been identified.

There are several considerations to include when developing the VEs. Freeman [2005] determined that presence and emotion are related only for arousing stimuli. Because it is widely believed VR is an arousing stimulus [8], we need to ensure a high standard of presence . Rivu et al. [2021] determined that emotion elicitation in VR is similar to reality. They determined that personalities do not affect emotions using a TIPI questionnaire, which assures us that our minimalist approach to questionnaires should not affect our results.

Finally, Freeman [2005] and Riva's [2007] studies have set a precedent for not disclosing the aims of their research, as the aim of emotion elicitation was not disclosed until after their experiments [6].

2.1 Sadness

Overall, there is little literature to draw from, and sadness elicitation in VR is a fairly novel area of research. However, Gilpin et al. [2021]'s study provides the closest model for how best to measure Sadness in VR [8]. While their study focused on how elicitation material influences the type of sadness produced, their sole focus on sadness and well documented measuring techniques are useful to us. Their findings offer a valid baseline for the physiological measurements we can expect.

Many of the measuring techniques and exclusion criteria we plan to use (outlined in section 4) have been taken from existing literature [7, 8, 9, 3]. Limitations to work relating to the elicitation of sadness that we hope to address in our work include small sample sizes [7], inadequate masking of objectives [8, 3], the measurement of multiple emotions in one study (which could lead to conflated emotions) [3, 21], and a lack of physiological measurements to supplement qualitative results [7, 9, 3].

2.2 Fear

Literature relevant to the Fear VE is more substantial, however, there are limitations. Meehan et al.'s study [11] provides an early example of a successful VE designed to provoke acrophobia, using physiological measures. The HMD-based VR setup was supplemented with wooden boards in the same configuration as girders, which the user would walk over. This simulated ledge acted as a passive haptic prop, ensuring the sensation of touching the edges of the girders in the VE was matched in reality. This enhanced user presence and has seen subsequent use in other height-based VEs, such as Kisker et al. [12].

When exposed to simulated fear-inducing stimuli, physiological markers of fear have been shown to increase significantly, and in correlation with presence [10,13,14,15,16]. A study by Madsen [2016] suggests that user control enhances fear evoked in a non-immersive horror video game. The experiment tested two groups, one playing through the game with limited control, the other watching the game. The interaction group's fear increased significantly more than the watching group, especially when user control was suddenly restricted. Despite this the only self-reported difference between the groups was perceived level of entertainment, also consistent with the physiological measures found [18]. This shows that fear may be heightened when control of a simulation is introduced, and suddenly restricted. This interaction also arose in a study by Lin [2018] in a VR horror game. Users with the highest subjective experience of fear displayed avoidance behaviours indicative of the activation of the fear structure in emotional processing [20]. Importantly, these behaviours were most prominent when users lost control of their weapon and could no longer protect themselves. Here, a loss of user control made users feel unable to cope with the already-frightening scenario, producing overt avoidance behaviour.

Literature on fear elicitation is limited in its investigation of the interaction between user control and emotional response. The few VEs testing this interaction have used horror games [17,19], which are designed for entertainment. This means they elicit emotions beyond fear, such as excitement and relief [22]. We will isolate the elicitation of fear to obtain empirically valid results.

3. Problem Statement, Research Questions and Aims

This project aims to explore how user interaction in a VE affects the level of emotion elicited. In the literature, tasks involving user control have been used to trigger certain emotional responses [12,17,19]. Because of this, it is assumed user control affects elicitation of emotion in VR. However, there exists little research investigating user control as an independent variable in emotion elicitation. We aim to address this problem to determine more effective ways to elicit emotions in VR. To do this, we will elicit Sadness and Fear in two separate VEs, with different methods of manipulating user control.

To understand our research questions, the context of each VE must be explained. The Sadness Environment will follow a narrative in which the user adopts a pet dog, bonds with the dog in a park, and then loses the dog when it is hit by a car. The main research question for this VE is:

- How does manipulating the amount of interaction with the dog in VR affect the sadness elicited when the dog dies?

The Fear Environment will involve the user being suspended on an elevated platform, above a city. They will be tasked with collecting machine parts, used to repair a lift in the centre of the platform. At a scripted point towards the end of the simulation, the user will lose their tool, becoming stranded in the dangerous situation. This interaction will act as the fear-stimulus event. The main research questions for this VE are:

- How does introducing interaction tasks to a height-anxiety based VE affect the level of fear elicited by that VE?
- What is the difference in fear elicited before and after a scripted event which leaves the participant unable to complete the stated interaction task of a VE?

The level of emotional elicitation in both environments will be measured with the following sub-questions:

- What is the user's psychophysiological response to fear- and sadness-inducing tasks in a VE?
- What is the user's self-reported emotional response to the events of the VEs?
- What is the correlation between self-reported measures of fear and sadness, and psychophysiological measurements when immersed in a VE?

4. Procedures and Methods

4.1. Design features

The Sadness Environment will be an improved version of an existing environment, created during a previous iteration of this honours project, and the Fear Environment will be a new environment. Both are subject to change after this proposal. In both scenarios, model assets will be sourced on the Unity Asset Store.

Sadness Environment

This VE involves a narrative over several locations. Users choose a pet dog at a shop, bond with it in the park, hear audio cues indicating a traffic accident, and receive the news that it has passed away at the vet. The environment's interactivity will be scaled to three levels, each allowing greater interactivity with the dog. The base level does not provide a choice of dog. The user also only interacts with the dog in the park using hand models. The next level allows the user to choose between three dogs, all with distinct personalities. The user is also able to navigate through the VE park and can interact with several contextual objects. The dog is more interactive in the park scene, and shows affection in a scripted event. In the highest level, the user can train the dog to respond to hand gestures, and can stroke it. They also experience a bonding moment with the dog when it leads them to a pretty grove with butterflies in the park. Finally, they also interact with it after it has been run over.

Fear Environment

The Fear Environment will involve a scenario designed to induce fear of heights. From the suspended platform, the user will interact with the machine parts and tool using the stock HTC Vive controller. Hand presence will be maintained with controller-tracked models in the environment. A base, low-interaction environment will allow the user only to navigate the elevated platforms. A second, high-interaction environment will involve the lift repair scenario, outlined earlier in the proposal. The event where the user loses their tool will occur after a fixed length of time has passed, or once the user has made a fixed amount of progress in the stated interaction task. To indicate that the scenario is over, despite the user not "escaping" by fixing the lift, the skybox and model lighting will shift to a sunset, and then darken to night, over the course of the remaining simulation period.

The environment will utilise a configuration of wooden boards to act as a haptic ledge below the user. This adds a tactile response to users placing their foot at the edge of the elevated platform, shown to enhance immersion [11]. The size of the testing environment (2,55m x 2,93m) must be considered to ensure the ledge is placed at a reasonable distance from the wall, while allowing for ample space to complete the tasks and retaining the "precarious" nature of the VE. Since the ledge cannot be dynamically oriented below the user, teleportation will not be used as a method of navigation to expand the size of the VE. Additionally, the haptic ledge may prove dangerous, due to the HMD obscuring user vision. The edges of the ledge must be clearly marked in the simulation and should provide ample space for movement, to avoid users from falling off.

4.2. Implementation strategy and Development platform

The VEs will be developed with the Unity game engine, using the Unity XR plug-in framework as the Software Development Kit. We plan to follow an iterative design process, in which each development cycle results in testable artefacts.

The initial iteration will produce a low-fidelity prototype of The Fear Environment. The Sadness Environment will also be evaluated for its relevance to the current research question and adjusted accordingly.

Subsequent design iterations will include implementation of the prototypes, and the incorporation for feedback after each iteration. As the VEs near completion, feedback will be acquired by informal evaluations from peers. This feedback will be in the form of pilot tests, which will assess the system's usability and basic performance qualities, and determine how long each experiment will take. This will inform our post-procedure methods. After several alpha iterations, including feedback from the pilot studies, the environments will undergo a heuristic evaluation (HE) from the project supervisors. From here, another iteration will be performed to incorporate feedback from the HE and finalise the VEs, which will be evaluated again by the supervisors and altered before they are finalised and used for the user study.

4.3 System Evaluation

4.3.1 Technical Fidelity

Throughout the iterative design process, the VEs will be evaluated for their technical fidelity.

Frame rate must be kept at a constant 60 frames per second. This is believed to sufficiently maintain presence in VR users as it is around the estimated capture speed of the human eye [23]. Inconsistent frame rates can cause visual effects of stuttering and lagging, which are detrimental to the user experience. Frame rates lower than 60 fps can also result in anomalous self-reported measures of emotion [24] and make simulator sickness more likely.

Latency refers to the delay between the tracking of the VR user's action measured by sensor hardware, and its visual representation on the HMD screen. This is measured on a timed motion-to-photon (MTP) scale and is also influenced by qualitative aspects of the visual display, such as tracking smoothness and accuracy [25]. Meehan et al. [2003] show that high latency (MTP $\geq$ 50 seconds) has a detrimental effect on the elicitation of emotion in VR, and VR best practice suggests the MTP should be no greater than 20 seconds [25]. Additionally, Juenet et al. [2018] showed that representations of actions in VR that diverge significantly from their real-world counterparts can cause users to feel they are not in control of the environment. This would damage the user's perception of interaction with the environment. As such, latency will be minimised through the use of quality hardware for rendering and controller detection.

Graphical quality has been shown to be non-essential in creating a VE suitable for eliciting emotions [4], however it must still be considered. Poor graphical quality can lead to ambiguous or unrealistic representations of real-world objects. This lends itself to creative interpretation by the participant, which could lead to unexpected results when measuring emotion elicitation.

4.3.2 Heuristic Evaluation

We will be using a modified version of Nielsen's usability heuristics adapted to a VR context by Sutcliffe & Gault [2004]. The HE of each VE will ensure they are of a high enough standard to produce reliable results. Our HE will include evaluating the following:

- Compatibility with user's task and domain
- Natural expression of action
- Close coordination of action and representation
- Realistic feedback

4.4 User Studies

This project will make use of 40-50 participates per VE, ensuring no overlapping participants. The participant pool will include undergraduate Psychology students who respond to our request for participation and meet our exclusion criteria. These criteria will ensure that participants who are predisposed to distress are not harmed from VE exposure. To participate in either environment, users must score below 45 on the *State-Trait Anxiety Inventory* (STAI). For the Fear Environment, users must score below 45.45 on the *Acrophobia Questionnaire–Anxiety Subscale* (AQ-Anxiety). For the Sadness Environment, users must score below 21 on the *Beck Depression Inventory–II* (BDI-II). Please see Appendix A for a thorough explanation of all three exclusion questionnaires. The remaining user pool will be made up of healthy, undergraduate UCT students. This will provide a diverse demographic for testing, with few dominant identity or personality traits to bias the data. No students with pre-existing relationships to the researchers will be included to ensure no conflicts of interest. Testing per subject, including post-immersion questionnaires, will be restricted to a 30-minute period.

4.4.1 Masking of Testing Purpose

Prior to immersion, the emotionally evocative nature of each environment will be intentionally obscured from the participants. This avoids the Hawthorne effect, which suggests user behaviour changes when specific testing outcomes are known [29]. The disclosure of the experiment purpose has been shown to produce skewed results [30], so must be avoided. The environments will be masked as follows:

- The Sadness Environment study will be proposed as an investigation of virtual dog training
- The Fear Environment will be proposed as a training simulation for construction workers in an elevated scenario

In this way, we hope to preserve authentic user responses.
To ensure user safety and adherence to research ethics standards, we have used the American Psychological Association's criteria for valid deception of research participants [2002]. We have ensured the deception involved in our study is justified by its significant benefit, given there is no alternative method for completing this research. This benefit is the novel contribution we will make to current literature. Because knowledge of an emotion-specific testing outcome will lead to contamination of the user's behaviour, we argue that masking is indispensable to produce valid results for the research questions.

Our exclusion criteria will ensure the disguised research will not cause physical pain or severe emotional distress to participants, and we will stop the experiment should simulator sickness occur. Finally, we will disclose the deception in a debriefing as soon as the experiment is over. This will allow users to understand the purpose of the, so they can choose whether to have their results withheld. Further post-immersion measures will include a guide to reduce simulator sickness symptoms, and extended support if negative feelings persist.

4.4.2 Measurement of Results

Data collection will occur during the procedure through physiological monitoring, and three post-immersion self-report questionnaires.

During Immersion

Cardiovascular measurement will be our objective measure of emotional response:

- We will measure heart rate (HR), respiration rate (RR) and electrodermal activity (EDA) using a Biopac system. These will be measured in a neutral environment before the experiment to provide a baseline for immersion.
- In the Fear Environment
  - We expect to measure an increase in HR and RR from the baseline [18, 40] due to the involuntary elicitation of fear [20].
- In the Sadness Environment
  - Previous research has indicated that VR is likely to elicit an activating pattern of physiological response to sadness-inducing stimuli [8], characterised by an increased HR and decreased RR.

Post-Immersion

To measure subjective experience of emotion we will use three questionnaires and include a presence questionnaire . Each user will be asked to fill out the *Visual Analogue Scale* (VAS) [41] to identify their primary emotion. *The Discrete Emotions Questionnaire* (DEQ) [42] will then be used as a more robust measure of possible co-present emotions. Finally, the *Self-assessment mannequin scale* (SAM) [43] will assess the elicited emotion on a dimensional scale. The *ITC-Sense of Presence Inventory* (ITC-SOPI) [47] will be used to measure presence. This is a quality control measure, testing for general user engagement. For a detailed explanation of these questionnaires, see Appendix B.

This combination of questionnaires provides the most comprehensive dataset for answering our research questions. However, it may not be time-feasible to employ all these questionnaires. Once the environments have been finalised, we will have a better idea of how long each experiment, allowing us to adjust post-immersion procedures accordingly.

4.4.3 Statistical Analysis

A between-subjects study will be used, and the results will be checked for normality. If they are normal, we will use non-parametric tests to further analyse the data. An ANOVA-based between-subjects analysis will be performed to identify statistically significant interactions.

5. Ethical, Professional and Legal Issues

We will involve human participants, so need ethics clearance. Factors that must considered are outlined below.
We aim to benefit the field of Psychology. We prioritise minimal risks, as we are unlikely to create explicit benefits to our participants, beyond possibly allowing them to fulfil their obligation for. This is not considered coercive, as students have

many opportunities to participate in research projects of their choosing.
Our project risks the possibility of lasting emotional disturbance, and motion sickness. We deal with this by excluding participants who are vulnerable to anxiety and depressive disorders. This exclusion criteria will also be applied to our second reader and pilot study participants. We will also brief participants about simulator sickness allowing them to fully consent. They can exit the VE immediately should simulator sickness occur.
We will collect free and informed consent prior to research with a consent form (Appendix C) signed by the participant and researcher. Any recordings or pictures will be subject to oral consent.

We aim to interpret our results accurately and report alternative interpretations. We will present our work using gender-neutral pronouns and ensure appropriate parties are credited. This is important for the project's code, as many third parties will have contributed. The VEs created will remain the property of the UCT Computer Science department should further work be necessary. All study-related data will be kept on a secure computer and will not be used beyond this study.

6. Anticipated Outcomes

6.1 Research Environments

Fear: We expect significant increases in participant psychophysiological measures in the high-interaction scenario, specifically after they lose the ability to complete their task. This will indicate interaction between user control and fear.
Sadness: We expect to observe direct correlations between activating sadness measured and the level of interaction with the dog. This will indicate an interaction between user control and sadness.

We expect both psychophysiological measures to be correlated with post-immersion self-reports.

6.2 Impact

Fear Environment: This experiment provides a novel example of experimental control in research investigating fear eliciting immersive VEs, by focusing on a non-gamified, non-horror scenario.
Sadness Environment: This research will address the lack of literature in the study of sadness elicitation in VR by isolating sadness from commonly co-present emotions. It will also provide an early example of the relationship between elicited sadness and user control.

Together, the results from both environments will contribute to creating better techniques for emotion elicitation in VR. This contribution can be used for various psychological applications and future studies.

6.3 System

The VEs will consist of various filetypes, associated with models, animation, and proprietary VR software. They will be runnable on the HTC Vive hardware. Each will have a series of relevant emotional triggers, expected to elicit emotion in participants. The VEs will adhere to the technical benchmarks and heuristic qualities outlined in section 4.3.

6.4 Key Success Factors

- Successful and timeous acquisition of ethics clearance for the user study.
- Production of technically-sound, emotionally affective VEs which do not harm experiment participants.
- Identification of a statistically significant interaction between user agency, brought about by way of user control and arousing stimuli, and the elicitation of the relevant emotion in each VE.

7. Project Plan

7.1 Risks

See Appendix D for a risk matrix.

7.2 Deliverables

Key deliverables include:
- Project Proposal
- Ethics Application
    - Two Beta Design Iterations
- Fully realised VEs
- Software Feasibility demonstration
- Draft of Project Paper
- Final Project Paper
- Final Project Code
- Project Poster
- Web Page

Please see Appendix E for a detailed timeline, including milestones, and Gantt Chart.

7.3 Resources

The resources required for this project are as follows:
Equipment:
- Experiment room(s)
- HTC Vive Pro Virtual Reality HMD
- Controller set
- Mounted sensors
- Desktop PC capable of running VR software
- Biopac
- Wooden boards for the Fear Environment

Software:
- Unity game engine (using the Unity XR plug-in framework as the Software Development Kit).
    - Open source – no need to acquire a license.
- Previous iteration of Sadness VE

- Models and skybox, acquired from the Unity Asset Store

People:

- 50 participants each
- Lab assistant with first aid training
- Peers for VE review
- Supervisors for HE and general advice

Measurement questionnaires:

- Presence questionnaire – ITC-SOPI
- Exclusion Questionnaires – AQ-Anxiety, BDI-II, STAI
- Emotion measurement – VAS, DEQ, SAM

7.4 Work division

All work related to the Fear Environment will be performed by Iain. All work related to the Sadness Environment will be performed by Julia.

[3993 words]

REFERENCES

[1] Ewa Siedlecka and Thomas F. Denson. 2018. Experimental methods for inducing basic emotions: A qualitative review. Emotion Review 11, 1 (2018), 87–97. DOI:http://dx.doi.org/10.1177/1754073917749016

[2] David R. Pratt, Michael Zyda, and Kristen Kelleher. 1995. Virtual Reality: In the Mind of the Beholder: Computer 28, 7 (July 1995), 17–19

[3] Radiah Rivu, Ruoyu Jiang, Ville Mäkelä, Mariam Hassib, and Florian Alt. 2021. Emotion elicitation techniques in virtual reality. Human-Computer Interaction – INTERACT 2021 (2021), 93–114. DOI:http://dx.doi.org/10.1007/978-3-030-85623-6_8

[4] Philip Lindner et al. 2017. Creating state of the art, next-generation virtual reality exposure therapies for anxiety disorders using consumer hardware platforms: Design considerations and Future Directions. Cognitive Behaviour Therapy 46, 5 (2017), 404–420. DOI:http://dx.doi.org/10.1080/16506073.2017.1280843

[5] Ville Mäkelä et al. 2020. Virtual field studies. Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (2020). DOI:http://dx.doi.org/10.1145/3313831.3376796

[6] Jonathan Freeman, Jane Lessiter, Katherine Pugh, and Ed Keogh. 2005. When presence and emotion are related, and when they are not. In Proceedings of the Conference at Presence 2005, London. Available at: http://www.temple.edu/ispr/prev_conferences/

[7] Giuseppe Riva, Fabrizia Mantovani, Claret Samantha Capideville, Alessandra Preziosa, Francesca Morganti, Daniela Villani, Andrea Gaggioli, Cristina Botella, and Mariano Alcañiz. 2007. Affective interactions using virtual reality: the link between presence and emotions. Cyberpsychology & Behavior 10, 1 (Feb 2007), 45-56. DOI: https://doi.org/10.1089/cpb.2006.9993

[8] Gina Gilpin, James Gain, and Gosia Lipinska. 2021. The physiological signature of sadness: A comparison between text, film and virtual reality. Brain and Cognition 152 (2021), 105734. DOI:http://dx.doi.org/10.1016/j.bandc.2021.105734

[9] Julia Diemer, Georg W. Alpers, Henrik M. Peperkorn, Youssef Shiban, and Andreas Muhlberger. 2015. The impact of perception and presence on emotional reactions: A review of research in virtual reality. Frontiers in Psychology 6 (2015). DOI:http://dx.doi.org/10.3389/fpsyg.2015.00026

[10] Julia Diemer, Lohkamp, N., Muhlberge., A & Zwanzger P. 2016. Fear and physiological arousal during a virtual height challenge—effects in patients with acrophobia and healthy controls. Journal of Anxiety Disorders 37 (2016), 30-39. DOI: https://doi.org/10.1016/j.janxdis.2015.10.007

[11] Michael Meehan, Brent Insko, Mary Whitton, and Frederick P. Brooks Jr. 2002. Physiological measures of presence in stressful virtual environments. ACM Transactions on Graphics (TOG) 21, 3 (2002), 645-652. DOI: https://doi.org/10.1145/566654.566630

[12] Joanna Kisker, Thomas Gruber, and Benjamin Schöne. 2019. Behavioral realism and lifelike psychophysiological responses in virtual reality by the example of a height exposure. Psychological research 85, 1 (2019), 68-81. DOI: https://doi.org/10.1007/s00426-019-01244-9

[13] Matthew Price and Page Anderson. 2007. The role of presence in virtual reality exposure therapy. *Journal of Anxiety Disorders* 21, 5 (2007), 742–751. DOI: http://dx.doi.org/10.1016/j.janxdis.2006.11.002

[14] Stéphane Bouchard, Julie St-Jacques, Geneviève Robillard, and Patrice Renaud. 2008. Anxiety increases the feeling of presence in virtual reality. Presence: Teleoperators and Virtual Environments , 17, 4 (2008), 376–391. DOI: http://dx.doi.org/10.1162/pres.17.4.376

[15] Ivan Alsina-Jurnet, José Gutiérrez-Maldonado, and María-Virgina Rangel-Gómez. 2011. The role of presence in the level of anxiety experienced in clinical virtual environments. *Computers in Human Behavior* 27, 1 (2011), 504–512. DOI: http://dx.doi.org/10.1016/j.chb.2010.09.018

[16] Merel Krijin, Paul M.G. Emmelkamp, Roeline Biemond, Claudius de Wilde de Ligny, Martijn J. Schuemie, and Charles APG van der Mast. 2004. Treatment of acrophobia in virtual reality: The role of immersion and presence. Behaviour research and therapy 42, 2 (Feb 2004), 229-239. DOI: https://doi.org/10.1016/S0005-7967(03)00139-6

[17] Kyle E. Madsen. 2016. The differential effects of agency on fear induction using a horror-themed video game. Computers in Human Behavior 56, (Mar 2016), 142-146. DOI: https://doi.org/10.1016/j.chb.2015.11.041

[18] Margaret M. Bradley, and Peter J. Lang. 2007. Emotion and motivation. In John T. Cacioppo, Louis G. Tassinary, and Gary Berntson, eds. Handbook of psychophysiology. 2007. Cambridge University Press DOI: https://doi.org/10.1017/CBO9780511546396.025

[19] Jih-Hsuan Tammy Lin. 2017. Fear in virtual reality (VR): Fear elements, coping reactions, immediate and next-day fright responses toward a survival horror zombie virtual reality game. Computers in Human Behavior 72, (2017), 350-361. DOI: https://doi.org/10.1016/j.chb.2017.02.057

[20] Edna B. Foa, and Michael J. Kozak. 1986. Emotional processing of fear: exposure to corrective information. Psychological bulletin 99, 1 (Jan 1986), 20-35. DOI: https://doi.org/10.1037/0033-2909.99.1.20

[21] Krista Lauwerijssen. 2008. Sadness. Bachelor's Thesis. Tilburg University, Tilburg, Netherlands.

[22] Jih-Hsuan Tammy Lin, Dai-Yun Wu, and Chen-Chao Tao. 2018. So scary, yet so fun: The role of self-efficacy in enjoyment of a virtual reality horror game. New Media & Society 20, 9 (Sep 2018), 3223-3242. DOI: https://doi.org/10.1177/1461444817744850

[23] Daniel Freeman, Sarah Reeve, A. Robinson, Anke Ehlers, David Clark, Bernhard Spanlang, and Mel Slater. 2017. Virtual reality in the assessment, understanding, and treatment of mental health disorders. Psychological Medicine 47, 14 (Oct 2017), 2393-2400. DOI: doi:10.1017/S003329171700040X

[24] Michael Meehan, Sharif Razzaque, Brent Insko, Mary Whitton, and Frederick P. Brooks. 2005. Review of four studies on the use of physiological reaction as a measure of presence in stressful virtual environments. Applied Psychophysiology and Biofeedback 30, 3 (2005), 239-258. DOI: https://doi.org/10.1007/s10484-005-6381-3

[25] Mohammed S. Elbamby, Cristina Perfecto, Mehdi Bennis, and Klaus Doppler. 2018. Toward low-latency and ultra-reliable virtual reality. IEEE Network 32, 2 (2018): 78-84. DOI: 10.1109/MNET.2018.1700268

[26] Michael Meehan, Sharif Razzaque, Mary C. Whitton, and Frederick P. Brooks. 2003. Effect of latency on presence in stressful virtual environments. In IEEE Virtual Reality, 2003. Proceedings, 141-148. IEEE, 2003. DOI:10.1109/VR.2003.1191132

[27] Alistair Sutcliffe and Brian Gault. 2004. Heuristic evaluation of virtual reality applications. Interacting with Computers 16, 4 (August 2004), 831–849. DOI:https://doi.org/10.1016/j.intcom.2004.05.001

[28] Camille Juenet, Louis Albert, Ferran Argelaguet, and Anatole Lécuyer. “Do you feel in control?”: towards novel approaches to characterise, manipulate and measure the sense of agency in virtual environments. IEEE transactions on visualization and computer graphics 24, 4 (Jan 2018), 1486-1495. DOI: https://doi.org/10.1109/TVCG.2018.2794598

[29] Berkely Rice. 1982. The Hawthorne defect: Persistence of a flawed theory. Psychology Today, 16(2), 70-74

[30] Daniel Västfjäll. 2001. Emotion induction through music: A review of the musical mood induction procedure. Musicae Scientiae 5, 1_suppl (2001), 173–211. DOI:http://dx.doi.org/10.1177/10298649020050s107

[31] American Psychological Association (APA). 2002. Ethical principles of psychologists and code of conduct. Available at: http://www.apa.org/ethics/code/index.aspx.

[32] Bruce L. Baker, David C. Cohen, and Jon Terry Saunders. 1973. Self-directed desensitization for acrophobia. Behaviour Research and Therapy 11, 1 (1973): 79-89. DOI: https://doi.org/10.1016/0005-7967(73)90071-5

[33] Bruce Arroll, Henry B. Wallace, Vicki Mount, Stephen P. Humm, and Douglas W. Kingsford. 2017. A systematic review and meta-analysis of treatments for acrophobia. Medical Journal of Australia 206, 6 (2017): 263-267. DOI: https://doi.org/10.5694/mja16.00540

[34] Shari A Steinman and Bethany A Teachman. 2011. Cognitive processing and acrophobia: validating the Heights Interpretation Questionnaire. Journal of Anxiety Disorders 25,7 (2011), 896-902. DOI:10.1016/j.janxdis.2011.05.001

[35] Aaron T. Beck, Robert A. Steer, and Gregory K. Brown. 1996. Beck Depression Inventory–II (BDI-II) [Database record]. APA PsycTests. DOI:https://doi.org/10.1037/t00742-000

[36] Robert A. Steer, Roberta Ball, William F Ranieri, and Aaron T Beck. 1999. Dimensions of the Beck Depression Inventory-II in Clinically Depressed Outpatients. Journal of Clinical Psychology 55, 4 (1999), 117–128. DOI: https://doi.org/10.1002/(SICI)1097-4679(199901)55:1<117::AID-JCLP12>3.0.CO;2-A

[37] David J. A. Dozois, Keith S Dobson, and Jamie L Ahnberg. 1998. A Psychometric Evaluation of the Beck Depression Inventory-II. Psychological assessment 10, 2 (1998): 83–89. DOI:https://doi.org/10.1037/1040-3590.10.2.83

[38] Charles D. Spielberger. 1989. State-trait anxiety inventory: Bibliography (2nd ed.). Palo Alto: Consulting Psychologists Press.

[39] Ozcan Kayikcioglu, Sinan Bilgin, Goktug Seymenoglu, and Artuner Deveci. 2017. State and trait anxiety scores of patients receiving intravitreal injections. Biomedicine Hub 2, 2 (2017): 1-5. DOI:10.1159/000478993

[40] Jamiah Hyde, Katherine M. Ryan, and Allison M. Waters. 2019. Psychophysiological markers of fear and anxiety. Current psychiatry reports 21, 7 (Jul 2019), 1-10. DOI: https://doi.org/10.1007/s11920-019-1036-x

[41] James J. Gross and Robert W. Levenson. 1995. Emotion elicitation using films. Cognition & Emotion 9, (1995), 87–108.

[42] Cindy Harmon-Jones, Brock Bastian, and Eddie Harmon-Jones. 2016. The Discrete Emotions Questionnaire: A new tool for measuring state self-reported emotions. PLOS ONE 11, 8 (2016). DOI:http://dx.doi.org/10.1371/journal.pone.0159915

[43] Margaret M. Bradley and Peter J. Lang. 1994. Measuring emotion: The self-assessment manikin and the semantic differential. Journal of Behavior Therapy and Experimental Psychiatry 25, 1 (1994), 49–59. DOI:http://dx.doi.org/10.1016/0005-7916(94)90063-9

[44] Mélanie Michaud, Stéphane Bouchard, Stéphane Dumoulin, and X. W. Zhong. 2004. Manipulating presence and its impact on anxiety. Presented at the Cybertherapy Conference 2004, San Diego, January 10-12 2004

[45] Rosalind W. Picard, Elias Vyzas, and Jennifer Healey. 2001. Toward machine emotional intelligence: Analysis of affective physiological state. IEEE Transactions on Pattern Analysis and Machine Intelligence 23, 10 (2001): 1175-1191. DOI:10.1109/34.954607

[46] Jon D. Morris. 1995. Observations: SAM: the Self-Assessment Manikin; an efficient cross-cultural measurement of emotional response. Journal of Advertising Research 35, 6 (1995), 63-68. Available at: https://psycnet.apa.org/record/1996-00218-005

[47] Jane Lessiter, Jonathan Freeman, Edmund Keogh, and Jules Davidoff. 2001.A cross-media presence questionnaire: The ITC-Sense of Presence Inventory. Presence: Teleoperators & Virtual Environments 10, 3 (2001), 282-297. DOI:https://doi.org/10.1162/105474601300343612

Appendix A

Acrophobia Questionnaire – Anxiety Subscale (AQ-Anxiety)
The AQ-Anxiety is a self-report questionnaire for assessing height-based anxiety [32]. It is widely used in testing for clinical acrophobia, and has been shown to have replicable results [33]. Participants must rate their anxiety when faced with a situation on a 7-point scale (0=not anxious at all, 6=extremely anxious). Any participants who score sufficiently high (≥ 45.45, as determined by Steinman and Teachman [2011] to be within one standard deviation below a subset of extreme acrophobics) will be excluded from testing in the Fear Environment.

Beck Depression Inventory – II (BDI-II)
The BDI-II is a 21-question self-report instrument used to assess and rate the cognitive aspects of depression in individuals [35]. The BDI-II is one of the most widely utilised analysis tools in this regard, as it has shown success in classifying significant depressive symptoms [36] and presents adequate retest reliability [37]. Participants will be excluded from testing in the Sadness Environment if they score ≥ 21, which indicates moderate to severe depression.

State-Trait Anxiety Inventory (STAI)
Finally, the STAI, a 20-question self-report questionnaire, will be used to determine whether participants suffer from general symptoms of anxiety, measured on a 4-point scale [38]. It has seen use as both a testing measure [7] and an exclusion criterion [8] in previous research involving the elicitation of emotion in VR, so is likely to be suitable for our study. Participants with an STAI score greater than 45 are classified as having high general anxiety [39] and will be excluded from both experiment scenarios.

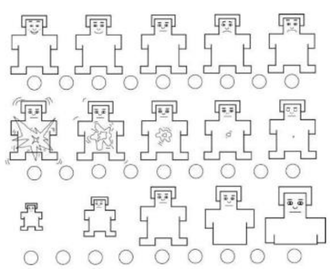
Appendix B

The Visual Analogue Scale (VAS): This is a variation of Gross's measure of emotion elicitation in films [7, 41] which assesses how participants feel with a rating for 7 possible discrete emotions. In this case, however, the participant will be asked to rate only the emotion that they first identified. In practice, this can take the form of a simple number ranking, otherwise, magnitude of experienced emotion can be visualised by a series of cartoon faces, which the user would be asked to choose from. In using such a simple initial measure, we hope to preserve the participant's overall impression of the environment, without giving them reason to endorse other emotions.

Discrete Emotions Questionnaire (DEQ): This instrument is designed to detect eight distinct emotions: anger, anxiety, desire, disgust, fear, happiness, relaxation, and sadness. It has been validated and compared against similar questionnaires, where it was found to be more sensitive at detecting self-reported emotions [42]. This is due to its ability to identify emotions that would otherwise be discounted by null effects on other measures of self-report [42]. The DEQ is quick to fill out and is built on a foundation of simple words used to describe emotions, all easily understood by English speakers.

Self-Assessment Manikin scale (SAM): This is a 9-point assessment that captures the intensity of an emotion by visualising the elicited emotion's valence, arousal, and dominance [44, 7]. Respectively, these characterise an emotion by the positive or negative feeling that it elicits, the strength of that feeling [7], and the participant's perceived ability to control the emotion in question [45, 7]. This scale has been validated in previous VR research of emotion elicitation, which found similar dimensional ratings of emotion to real-world stimuli [7]. It was proposed as an alternative to more inefficient verbal self-report measures [46]. However, as recognised by Rivu et al. [2021], it is suggested that objective physiological measurements be used alongside SAM to garner more substantial results.

FIGURE 1
SAM The Self-Assessment Manikin



ITC-Sense of Presence Inventory (ITC-SOPI): The ITC-SOPI is a 44 question self-report questionnaire used to measure a user's subjective sense of presence in any immersive experiential medium [47]. It uses a 5-point Likert scale with questions in order to determine various factors of presence, including: whether the user felt physically embodied in the scenario, whether the user believed the events were actually occurring, among others.

University of Cape Town: Virtual Reality Consent Form

We are a group of UCT students researching the best way to create training environments in Virtual Reality (VR). This study will comprise either a construction or dog park environment, in which you will follow a few prompts. We will measure your physiological reactions to the environment and ask you to fill out 4 self-report questionnaires afterwards. The researcher will explain the environment you will experience in more detail. Please read the following information, contact us with any questions, and sign to consent to participate.

I… .... voluntarily agree to participate in this research study.

- I understand that even if I agree to participate now, I can withdraw at any time or refuse to answer any question without any consequences of any kind.
- I understand that I can withdraw permission to use data from my study within one week after the study, in which case the material will be deleted.
- I have had the purpose and nature of the study explained to me in writing and I have had the opportunity to ask questions about the study.
- **I understand that participation involves experiencing a VR environment that may cause simulator sickness, the details of which will be explained in person.**
- I understand that I will not benefit directly from participating in this research.
- I understand that all information I provide for this study will be treated confidentially.
- I understand that in any report on the results of this research my identity will remain anonymous. This will be done by changing my name and disguising any details of my data which may reveal my identity or the identity of people I speak about.
- I understand that my physiological measurements and questionnaire answers may be quoted in all related documents for the UCT Honours VR project.
- I understand that signed consent forms, questionnaires, and all measurement recordings will be kept on the researcher's private hard drive until this project is completed.
- I understand that a transcript of my interview in which all identifying information has been removed will be retained until the fourth year UCT HCI course is completed.
- I understand that under freedom of information legalisation I am entitled to access the information I have provided at any time while it is in storage as specified above.
- I understand that I am free to contact any of the people involved in the research to seek further clarification and information.

Signature of research participant.......................................Date...............

I believe the participant is giving informed consent to participate in this study

Signature of researcher.......................................Date ....

Appendix D

Risk Condition	Consequence	Cat	Prob	Impact	Mitigation	Monitoring	Management
Load shedding	Project schedule and development would be disrupted. Communication between team members and supervisor may also suffer.	Scheduling	High	Low	All team members have Eskom Se Push so can schedule around load shedding alerts.	Enable push notifications for load shedding app.	All members must communicate their loadshedding schedules with one another, so that plans can be made to ensure that communication remains seamless. Team members should also ensure that their devices will be charged if necessary.
Misunderstanding Supervisor requirements	Time wasted planning /implementing out-of- scope requirements. Poor implementation of requirements. Useless results.	Scope	Low	High	All correspondence with supervisors is stored as meeting minutes in MS Teams.	Maintain communication with supervisors to ensure that the correct understanding is achieved. Submit drafts in time for feedback to ensure that our direction is correct.	Get a clear understanding of incorrect/ missed requirements and add them to the schedule, which may include adjusting the schedule.
Team member(s) contract(s) Covid-19 / is otherwise unwell	The affected team members may be slowed down, hampering project progress.	Human Resources	Low	Medium	Continue to follow Covid-19 Protocols and maintain a healthy lifestyle with few risks.	Team members should notify each other of health problems, and encourage each other to continue to follow Covid-19 protocols.	Inform the supervisors of the infection. Allow team member time to recover, and assess the effects on the project schedule and active tasks.
Team member struggles with VE implementation.	The environment may not pass the heuristic evaluation / pilot studies, and will need to be reworked or even restarted. This would hinder project progress, as a complete VE is a required to perform most of the project.	Technical	Medium	High	Ensure that both team members have completed a sufficient Unity and C# tutorial before development begins, and that they fully understand previously coded environments.	Team members should regularly report parts of the code that are problematic (e.g. have bugs or are not well graphically designed). Team members should be able to access help from one another and supervisors.	The team should discuss any issues and attempt to overcome them within the scheduled time. This could include sharing resources and having peer code review sessions.
Ethics Clearance is not acquired	No research with human subjects will be performed, and so the system will not be tested, which will make the project have no purpose.	Scheduling	Low	High	Hand in completed ethics clearance request as soon as possible by setting an early deadline and sticking to it.	Ensure that all communication with the ethics committee is responded to timeously and without error.	Prepare the best version of VEs possible, so that testing can begin earlier next year.

An insufficient number of research participants is acquired	Our results will be less valid and therefore not publishable.	Human Resources	Low	High	Send out recruitment forms well in advance, and use the pool of Psychology students who are required to partake in research projects	Continue to send out reminders if not enough responses are received.	Either perform the study with fewer participants, and ensure to note this limitation in findings, or reschedule the experiment to a time when more participants are available.
Research participants having a severe negative response to the VE	The results for that participant will be unusable, and the participant may experience trauma	Technical	Low	Medium	Ensure that all participants meet the pre-screening requirements to partake.	Brief participants on their ability to opt out, and on simulator sickness. Monitor them for any distress during the experiment.	Have a lab assistant with first aid experience available at all times, and include a debriefing session at the end of the experiment
Team member is not keeping up with their commitments to the project.	The project progress will be delayed, and the final submission could be adversely affected because certain features or requirements are missing.	Human Resources	Low	High	Both team members will have a clear understanding of their role before any development starts. Potential scheduling conflicts must be accounted for well in advance.	The Gantt chart will be continuously updated to track progress, which allows the team members to keep themselves and each other accountable. MS Teams will also be used to store meeting minutes and documentation, so that both team members remain on the same page.	The scope of the project should be adjusted to ensure that missing work has as small an effect on the project outcomes as possible. Unfulfilled commitments should be reported to the supervisors. We should discuss why the commitment was unfulfilled and plan for it not to happen again.
Scope Creep	Resources wasted on unnecessary work.	Scope	High	Medium	Have a well-defined set of features to be implemented before development starts.	Ensure that the decision to include any new features is deemed necessary by the team and supervisors, and strive not to include any features that are not directly related to the project goal.	Adjust the schedule so that important features become the focus, and assess the impact of the resources lost to out-of-scope work.

Appendix E

Name	Begin date	End date
Proposal	2022/05/19	2022/07/14
Proposal draft writing	2022/05/19	2022/05/21
Proposal draft hand-in	2022/05/22	2022/05/22
Proposal presentation preparation	2022/05/19	2022/05/23
Proposal presentation	2022/05/24	2022/05/24
Proposal writing	2022/05/22	2022/05/26
Proposal hand-in	2022/05/27	2022/05/27
Revised proposal writing	2022/07/01	2022/07/14
Revised proposal hand-in	2022/07/15	2022/07/15
Ethics Application	2022/05/19	2022/07/10
Initial application writing	2022/05/19	2022/06/09
Initial application hand-in	2022/06/10	2022/06/10
Final application hand-in	2022/07/11	2022/07/11
Development	2022/06/06	2022/07/31
Iteration 1	2022/06/06	2022/06/19
Iteration 2	2022/06/20	2022/07/03
Iteration 3	2022/07/04	2022/07/17
Pilot tests	2022/07/18	2022/07/19
Realised environments	2022/07/20	2022/07/20
Heuristic evaluation	2022/07/20	2022/07/22
Finalise code	2022/07/23	2022/07/31
Software feasibility	2022/07/25	2022/07/25
Development complete	2022/08/01	2022/08/01
Study	2022/07/18	2022/08/23
Send out recruitment forms	2022/07/18	2022/07/29
Validate participants	2022/07/29	2022/07/30
Participants Finalised	2022/07/31	2022/07/31
Carry out study	2022/08/01	2022/08/12
User study complete	2022/08/13	2022/08/13
Analysis	2022/08/13	2022/08/23
Final Paper	2022/08/11	2022/09/01
Final paper draft writing	2022/08/11	2022/08/22
Final paper draft hand-in	2022/08/23	2022/08/23
Final paper writing	2022/08/23	2022/09/01
Final paper hand-in	2022/09/02	2022/09/02
Final Code hand-in	2022/09/05	2022/09/05
Demonstration Preparation	2022/09/05	2022/09/18
Demonstration hand-in	2022/09/19	2022/09/19
Poster Preparation	2022/09/26	2022/10/02
Poster hand-in	2022/10/03	2022/10/03
Website Preparation	2022/09/25	2022/10/09
Website hand-in	2022/10/10	2022/10/10