The Effect of Interaction in the Elicitation of Emotion in Virtual Reality

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1. Project Description

Mental disorders, phobias, and other mental health issues are problems that are, and will continue to be, prevalent in the current world. One technique proven to be effective in helping people deal with these is exposure therapy [1], which involves exposing the patient to the source or context of their mental health issues in a safe environment with the intention to overcome their distress. Virtual Reality (VR), the use of technology to create a simulated environment, has been shown to be an effective medium [2] and is able to manipulate the environment of the patient in an easy and safe way. VR is also becoming more prevalent in general use, especially in the entertainment industry.

Interaction, the degree to which users of a medium can influence the virtual environment (VE), is one of the key features of Virtual Reality that sets it apart from other mediums, yet there has surprisingly been minimal research on its effect in evoking emotions. Being able to manipulate emotions not only gives us a better understanding of them, but also shows us how we can provide better therapeutic treatment or better entertainment experiences.

Our focus in this project is on eliciting two specific emotions, sadness and fear, due to the already existing VEs for each which were created by previous students in earlier stages of this project. These existing environments allow for the desired emotions to be elicited and for us to alter them to see the effect interaction has on this elicitation. It is also easier to manipulate and measure the elicitation of a single emotion in a VE and thus why each VE is focused on a single emotion. We will add a tool to each VE to adjust the amount of interaction that takes place and improve the Artificial Intelligence (AI), which in this context, is the use of algorithms to generate responsive and adaptive behaviors primarily in non-player characters, similar to human-like intelligence. These emergent behaviors, where the AI can have lots of different reactions to different events, which occur are important for making the reactions of VE seem more realistic and the VR experience more immersive. The measuring of the interactions and AI will be done through heuristic evaluation, interaction scenarios and emotional measurements. These methods raise small ethical issues due to the sensitive nature of emotions and its effect on the participants' psychological state but will tell us whether the interactions are effective.

2. Previous Work

Research conducted in the field of virtual reality, psychotherapy and emotion elicitation often refer to two terms, presence and immersion, as a driver for evoking emotion. The definition of these terms varies considerably [3]. To avoid confusion, we present immersion as an umbrella statement, as first outlined by Mutterlein [4]. That is, immersion is the subjective psychological experience of the user in the virtual environment, that is restricted by the technology of the VR system. This allows the terms to be used interchangeably.

Fear is rooted in the evolutionary notion of "survival of the fittest" and threats from predation. Cosmides and Tooby [5] define that humans have an innate response of fear when alone at night; a feeling of being "stalked." VEs in fear use this psychological instinct of human adaptation as a core mechanism in evoking immersion and fear: presenting the user in a dark, eerie environment which immediately sparks a sense of terror. Along with dark presentation in VEs, non-interactive environments [6, 7, 8] use a combination of visual, audio and kinesthetic scripted cues to arouse a sense of fear further. This is achieved through surprising audio and visual cues ("jumpscares"), exposing highly stimulating virtual entities to the user (such as spiders, monsters, supernatural creatures) and tactile feedback (motion and vibration). It is also evident that realism in the VE through high resolution textures and model polygon counts, with the addition of high-fidelity VR technology, heightens fear even more [7]. While effective in eliciting fear, it is interesting that [9], an interactive environment, found that barring control of a weapon from the user in the presence of a scary enemy resulted in the strongest fear response in the user. This leads to an investigation of agency in the user, among other interaction techniques such as presenting the user with virtual hands [10] - allowing manipulation of visual, audio and kinesthetic elements, as the core mechanism in eliciting fear in interactive VEs. Manipulating the users' agency could create the pinnacle of fear elicitation, and there is a gap in research pertaining to the effect of interaction and agency in VR.

The desired type of sadness identified to be elicited is parasympathetic withdrawal which similarly, is related to the user having agency where a loss is imminent, but is not inevitable [11]. There are several factors which hold influence as to when this type of sadness is elicited to which attachment is one of the strongest; if the user has a stronger attachment bond between people, then in the event of loss, a larger extent of grief is

experienced [12]. In VR, these attachment bonds can be formed between the user and the virtual character avatars, they are not formed between humans only and rather from the dual elicitation of emotional responses from the bonding participants and the shared activities between them [12, 13]. Another factor which not only affects elicitation of sadness, but also attachment, is empathy [13, 14]. This relies on affective communication between the participants and agency belief - the participant's belief about the virtual agent having agency. Another commonly used technique in eliciting sadness is visual imagery and mood has also been found to have an impact [14]. Finally, elicitation is caused by events [15]. This event needs to be against the participant's motive, what the participant wants or desires to happen, and event-directed, where the participant does not relate the cause to an agent, but rather to circumstance. This area of research, sadness in VR, however, remains subject to investigation due to limited resources.

2.1 Artificial Intelligence

An Artificial Intelligence (AI) Director is an AI that features a dynamic system for game dramatics and pacing, making changes to the game environment to enhance the experience [16]. It decides where game objects and agents spawn and how often these occur based on dynamic elements, such as the players skill, the time since a previous attack or how close they are to the end of the level. The AI Director is an overarching control of the system and makes changes to the overall experience. On the other hand, AI agents make use of techniques such as decision trees, pathfinding, scripting and adaption to create a dynamic and improved experience. These are related to specific characters in the environment and focus on their behaviour. Both of these, AI Director and AI agents, have been identified as the core aspects of AI in this project

2.2 VR Measures

Heuristic Evaluation [17] is a method for finding usability problems in a user interface design by having a small number of evaluators examine the interface against a set of usability principles, the heuristics. It has been shown that the aggregation of several evaluators to a single evaluation is able to do well in finding usability problems, even when the group consists of three to five evaluators. It has also been shown that specialists in the field provide better evaluation than non-specialists [18].

In VR, heuristic evaluation is slightly different from traditional methods. VR can follow Sutcliffe and Gault's method of 12 specialized heuristics adapted for VR software [20] These, like Nielson's heuristics [17], are rated on a severity scale of 0-4, indicating the severity of the problem associated with the heuristic and a design feature from the VR system.

We next aim to present a simple method for measuring immersion and emotion, and since these are abstract in nature, an effective method of measuring the experience in VR is needed, for which the discrete emotions questionnaire [19] will be used.

3. Problem Statement and Research Questions

While there has been much research done in the field of VR, emotion and psychology, there has been a lack of research on the effect of interaction on emotion in VR. Although there have been virtual environments created and used for eliciting fear and sadness, no environment has been created with the capabilities of controlling the nature of interaction taking place. Finally, there has been a lack of Artificial Intelligence (AI) agents in these experimental VEs with the capabilities of reacting to participant's actions, which would give a stronger sense of agency and intelligence. This final issue has been changed to one of the main focuses of the project due to the COVID-19 disease preventing human experimentation.

This leaves two clear goals for this project, which are as follows:

1. Create a virtual environment which can manipulate the amount of interaction between the participant and the environment by increasing or decreasing the potential interactive events or actions that the participant can do.
2. Create an AI in the virtual environments that reacts to the participant's actions by dynamically altering the environment or the AI's behavior.

Each of these goals center around interaction in VR and lead to this project's proposed research questions:

Will the manipulation of the number of interactions in a VR environment between the participant and the VE cause an increase in the elicitation of the desired emotion?
Can AI be used in VR to create a greater sense of agency in the participant?
Can AI be used to support interaction in virtual environments?

The first goal is the pillar of the project, allowing future experimentation to take place by creating the environment within which to perform it, and with the second goal providing a more intelligent AI which enhances the illusion of agency and improves the interaction experience. The AI will be improved by modifying the algorithms of the agents and by the addition of an AI director in the system. The third goal allows the changes caused by interaction and AI agents which occur within this environment to be observed and measured.

4. Procedures and Methods

This section discusses the design and implementation strategies for setting up the virtual environments and experiments. To achieve the goals of this project, two virtual environments will be developed, one for sadness and one for fear. There will also need to be two sets of heuristic evaluations, each using a separate environment and measuring the environment responses to actions and the emergent behaviour that occurs. These evaluations will follow an identical procedure. Agent AI is a focus instead of human experimentation, and as such the AI will be created in each virtual environment separately as they will differ due to the contrasting requirements of the two environments. The division of workload for this project will occur between the emotions with

each member focusing on the environment and AI agents which occur within them relating to one of the emotions.

4.1. Heuristic Measurements

Heuristic evaluation by experts in the VR field is the core measurement of the success each environment has in eliciting emotion. Each VE will be evaluated using the methods Sutcliffe and Goults defined for VR Heuristics measures [20]. The structure of this measure revolves around three core categories:

1. Problems (from design classes)
The evaluator is required to present a problem within a design class that refers to a group of design features. For example, a design class would be interaction using virtual hands.

2. Associated heuristics
Once a problem has been identified, an associated heuristic is allocated to the problem. For example, interaction using virtual hands could present a problem with physics and will be associated with the *Realistic feedback* heuristic.

3. Severity of the problem
Finally, a severity rating from 0-4 is assigned to the problem and heuristic. Continuing the example above, a severity rating of 3 will be given to the problem, as unrealistic physics could break immersion.

4.2. Interaction Scenarios

Specific Interaction Scenarios, where an action which should cause the system to react in a certain way is tested, will be constructed for a portion of the interactions. This method will involve a defined user action and the corresponding reaction from the VE that should occur, each of which will be tested. The AI reactions which occur will also be included, as they similarly will change based on the participant's actions. These cannot be done for all the interactions and AI reactions due to the emergent and unpredictable desired behaviour - as environment interactions can be unpredictable given the autonomy of user decision.

4.3. Interaction and Emotion Measurements

While heuristic measures for VR environments are accounted for; there is a need to link emotions to the associated experience of the user while they are in the VRE. We use a combination of the discrete emotion questionnaire [19] and our own novel logging system to achieve this correlation of environment triggers and emotional response. At the precise moment of an interaction that triggers a dynamic environment event, this event will be logged and used in the emotion evaluation; as the log will be available to the evaluator following the experience. Evaluators will be requested to select the most fitting emotion and rate it from a range from one to seven with one being not at all and seven being an extreme amount for each interaction logged. Each of these words will converge to one of the following discrete emotions: anger, disgust, sadness, fear, anxiety, relaxation, desire and happiness. There are four words linked to each discrete emotion and the large range will provide us with the information of which interactions cause wanted or unwanted emotions and the level of these emotions. An open-form baseline measurement will occur prior to the VR experience through verbal means and compared to a similar measurement taken afterwards. This questionnaire will form a part of the heuristic evaluation, making sure that each environment is causing the right effect and that the interaction has an effect.

The AI director in each environment works in conjunction with interaction to attempt to elicit emotion through emergent behavior. While manual evaluation on the success of this is effective, logging the change in the environment at the moment of its trigger is useful to extract the time of emergence and emotional response. When the user interacts with the VE in a certain way, the AI director will modify the users' experience and append the log with exactly what changed in the environment and when. This will plot the path the user proceeded to take throughout the experience, and help us identify which actions lead to a better emotional response and behavioral changes in the user.

4.4. The Virtual Environments

Each extant environment will be further developed using Unity game engine and is experienced using the HTC Vive headset as a controlled variable; which has a resolution of 1080 x 1200 pixels per eye, a 90hz refresh rate, 110 angle field of view and two motion controllers that act as virtual hands. This produces an immersive experience in the developed environments as it resembles a closer resemblance to reality than older generation headsets. Each environment contains elements related to their emotions, AI and interaction.

4.4.1. Design Methodology

A software development project requires a design methodology that adequately prepares developers for design challenges and expectations. For development of each VE, we will follow the agile, user-centred design model that focuses on iterative software development cycles and constant user feedback for each cycle. For each prototype of the project, we assign names that correspond to our phases of development. We initiate development with a paper prototype depicting the birds-eye view of both extant VEs with a rough overview of additions, interaction triggers and dynamic environment paths. Next major development iterations include alpha, beta and final releases. After each release, supervisors and allocated testers will evaluate and provide feedback for our next cycle through a testing framework where we outline each new feature added.

The interaction paradigm for the VEs is centred on a gradient pip slider that correspond to additional features. Prior to entering the VE, the user uses the slider to choose a pip or level of interaction; whereby underneath the slider contains descriptors for all elements at each level of interaction.

4.4.2. Fear

The extant fear environment contains scripted events that are meant to frighten and produce an atmosphere that evokes a fear response in the user throughout the experience. The user is placed on a boat that is guided through a dark tunnel, which is interrupted by virtual entities such as monsters. The combination of the fear of the unknown, a very dark environment, the sounds of water and the sound of the monster culminates in an overall scary experience. This is the current state of the environment, and is

used as the control - with the addition of increasing texture resolution, adding binaural (3D) audio, and an increase of model polygon counts of the monster to enhance realism and evoke fear even further.

The AI of the monsters is to be altered so that the virtual entities are no longer simply scripted to appear; but rather chase the player using a pathfinding algorithm and decision trees. This allows the monster to manipulate the agency of the player, as the player now has to worry about if, for instance, the monster is around the corner of the tunnel. Also, an AI director will act as a controller for the environment, and dynamically change the environment based on triggers and inputs by the player. For example, if the player chooses to navigate a certain corridor, the agent will spawn in different locations, and certain rooms will be shifted to aid or prevent the escape of the player. The addition of a goal for the player to reach the end of the environment without being caught will add to this threat to the agency of the participant.

Interaction is the primary addition to the environment, and acts as the focus of this study. An interaction slider can be used to change the level of interaction depending on the stage of the experiment. Once the slider is adjusted past no interaction, the users will be presented with virtual hands that can be used to interact with the world, such as picking up a firearm and a torch. The boat and water will be on a dynamic path, and the user can decide to take different routes through different tunnels. When the enemy attacks the user, the user can wave their torch to scare away the monster; it will simply run away and return at a later stage. Eventually, the player will need to reach the end of the level and reach their goal - but not every canal leads to the end. Additional resources that are planned to be added to increase interaction in the environment include a radar device that reveals a blip of the monster if it is near, with an increase of heartbeat and breathing rate audio, and shadows that resemble monsters that are not there, that change depending on torch orientation.

4.4.3. Sadness

The current sadness environment contains four scenes which are used to convey the different parts of the story. The first scene is a simple one where the participant chooses whether they are left or right-handed, allowing them to be more immersed as they use their predominant hand in the environment. The second scene involves the participant choosing the dog at the pet store, and in the third scene they play with the chosen dog in the park, throwing a ball for them until the dog is hit by a car. The final scene occurs at the vet, where the participant is handed the ball they were throwing in the park and is told that the dog will not survive, that it will die. The combination of choosing the dog at the pet store and playing with them in the park, by throwing a ball, help the participant form an attachment bond with the virtual dog. The scripted events which then occur in the park lead the dog into being hit by a car and the vet scene leads to the participant experiencing sadness due to the loss. This existing environment will be altered slightly for the control, removing some of the existing interaction to create a larger contrast between it and the environment with the focus on interaction.

Interactions added will be to improve three aspects of the environment which have a strong influence in the elicitation of sadness. Firstly, the participant will be given more agency and a greater sense of it visually and with the ability to interact with more objects. This will be done by allowing the user to navigate through the environment and interact with the objects that exist in it, such as sticks in the park, or communicating with the dog through gesture recognition. The control environment will remove some already existing interaction, providing us with a greater contrast, such as removing the ability to choose the pet. Secondly, interaction that is added between the participant and the dog will primarily be to create a stronger attachment bond between them, this will be done by allowing the user to pat the dog, follow it into a beautiful patch of butterflies or train it with hand gestures. The stronger the bond, the more loss is experienced.

These moments of loss are the third aspect, and the interactions that happen around them will be increased by allowing them to be by their pets side once it has been hit by the car and comfort it or grabbing the ball from the vet and seeing the dogs name on it. The amount of these interactions that occur in the environment will be able to be manipulated based on the settings selected beforehand.

The AI of the dog and the overarching narration will be enhanced, which will be able to be manipulated for future experimentation. The improvement in the dog's AI will give them a greater sense of agency, and the dogs in the store will react more realistically and differently, giving each a sense of individuality or personality. The chosen pet will change responses dynamically depending on the participant's actions. These responses will change depending on the actions which the participant takes while in the environment making use of emotional behavioral trees and scripting. The overarching narration will be manipulated by the AI Director based on the participants actions and certain interactions that occur will cause changes in the environment. These manipulations will create a VE which is more dynamic and where the participant's actions have more influence on it.

4.4. Procedure

The first task is to begin recruitment of those who are willing to participate in the heuristic evaluation. This is done through communicating to members of UCT staff and postgraduate master's students who specialize in computer science and have access to a VR system - with the help of our supervisor. Around four to five evaluators would suffice as this is an expert evaluation. Once recruited, we require signed consent from the participant, and the consent form would include disclosure of sensitive material during our study and advises that those with mental health issues should not participate.

Once the consent form is returned to us, we explain the nature of the experiment and the procedure of how the participants relay information to us. They are then required to take open form baseline emotion tests to act as a control for their emotional state, and begin the experiment. Participants are to experience all four VEs (control fear, fear, control sadness, sadness) with a minimum ten-minute break between each pair. The encounter with each pair of VEs begins with the control VE, where they are subjected to

little to no interaction - whereby the interaction slider is set to none. Once the experience ends, the evaluation (heuristics and emotion measures specific to the VE) are completed. Next, the newer VE is tested; where the participant experiences the VE twice - first with moderate interaction and second with full interaction. Only two options are available to avoid complications. The evaluator then, as before, completes the measures, and each method of interaction is clearly defined, with open ended fields in the form in the case that emergence occurred, or if they simply want to add more measures from their experience.

During this process, they may also make use of logs and screenshots generated during each run of the VE to aid them in evaluation. Once both VE pairs have been experienced, the completed form and logs are to be returned for our analysis.

5. Ethical, Professional and Legal Issues

The majority of the ethical concerns of our research centres on the participants of our heuristic evaluation and their exposure to virtual environments that may induce fear and sadness, two emotions that are often related to mental issues and require correct ethical clearance and disclosure before experimentation.

This type of research requires ethical clearance via application through departmental superiors who evaluate the procedures of our studies and ethical parameters of our application. To initiate and get approved clearance from the science faculty, this application must be sent as early as possible.
This application contains important information such as the administrative aspects of the project (e.g. area of research, objectives and participant requirements).

The project will make use of heuristic evaluation which will need to be done by a group of professionals. Due to the sensitive nature of the experiments, safety of these professionals is a high priority. They will be required to not be at risk of having Post Traumatic Stress Disorder (PTSD), depression or other mental disorders to prevent relapse. The screening will be brief, where the participant will be required to confirm that they are not at risk of any aforementioned mental disorders. They will also have simulation sickness, which is similar to motion sickness but occurs in simulated environments, explained to them and it will be reiterated that should they experience this or other discomforts in an overbearing way, they should withdraw and another professional should do the evaluation instead.

Since this research is conducted under supervision from departmental staff and the university itself, UCT reserves the right to own the product of this experiment. Publication is at our supervisors discretion, and is not necessary in contributing to the success of the project. All legal issues surrounding the project are directed towards the researchers of the project and ultimately UCT.

6. Anticipated Outcomes

6.1. AI

The VEs will require a certain level of AI that makes use of two core AI concepts. AI agents and AI directors. Agents in both VEs should resemble virtual entities that create the illusion of intelligence and decision making. This is to be done through techniques such as decision trees, pathfinding, scripting and adaption. In conjunction, the role of an external AI director will act as a controller against each environment, manipulating the users' experience in a dynamic way - leading to emergent behavior and non-linear navigation of each environment. This could create unexpected experiences for the user and could elicit behavior that is unprecedented in non-interactive VEs when combined with interaction.

6.2. Interaction

Each VE is expected to have a tool that can accurately define the level of interaction in the VE. We will adjust this tool accordingly depending on the response we wish to record. The tool would consist of a pip slider which relates to different levels of interaction, with the lower levels having less interactive and AI elements present than the higher levels. Each level of interaction will be clearly communicated through description of every change to the VE. The realism of the environment will also be modified through modification of texture resolution and polygon counts of models, and as a result, the VE will strike a balance between realism and uncanny valley effects [21], the degree of realism that remains appealing to the user, for optimal comfort. Interaction in each environment depends on the emotion: we expect the user in the sadness VE to interact with the dog through techniques that increase the attachment bond between the participant and the dog and manipulate the interactions of loss and their sense of agency. In the fear VE, we expect interaction with doors, weapons, levers, the monster and various dynamic objects.

6.3. Key Success Factors

The success of the project depends on the previous core factors: can each virtual environment use AI and interaction to successfully elicit emotion - more so than non-interactive VEs. The role of AI is crucial to support interaction and provide a greater sense of immersion, which ultimately leads to stronger emotional response from the user.

When the user experiences and utilizes these interactions in both VEs, we expect, in our evaluations, that due to the interaction and AI in each new VE, there is a greater sense of fear and sadness elicited than in the extant VEs .

7. Project Plan

7.1. Risk and Risk Strategies

The risk matrix represents specific problems that may occur during the research process. Each risk has an associated severity and probability of occurrence. We have defined ways of mitigating, monitoring and managing each risk appropriately. See appendix A for our risk matrix.

7.2. Timeline

The timeline has been set to start after the June exam block and after the proposal has been revised and finalised, with the work done before this being an inspection of the existing code.

The majority of time will be spent on the coding of the environments and agents, until the evaluations are done. From this point, the focus is on the other deliverables for the project.

The coding will be done in phases, or iterations, with user testing done after each, identifying missing or weak features. The next phase will build from the previous based on the feedback, adding or improving the features identified. The first phase done will be a paper prototype, where all the intended features will be included. These will be adapted and refined in the software in the subsequent phases. The final testing phase will be to ensure that no bugs are present in the final environment.
See Appendix B for Gantt Chart.

7.3. Resources

The required resources for this project are as follows:

- Existing sadness and fear environments and assets,
- HTC Vive HMD, motion controllers and tracking base stations,
- Heuristic evaluation, interaction and emotion forms,
- Premium Unity assets.

8. References

[1] Krijn, Merel, Paul MG Emmelkamp, Ragnar P. Olafsson, and Roeline Biemond, 2004. Virtual reality exposure therapy of anxiety disorders: A review. Clinical Psychology Review, 2004, Vol.24(3), pp.259-281. DOI: https://doi.org/10.1016/j.cpr.2004.04.001

[2] Amy Karon, 2015. Exposure-based therapy best for complicated grief. Clinical Psychiatry News, vol. 43, no. 2, pp. 25

[3] Mel Slater, and Sylvia Wilbur, 1997. A framework for immersive virtual environments (FIVE): Speculations on the role of presence in virtual environments. Presence: Teleoperators & Virtual Environments, 6(6), 603-616.

[4] Joschka Mütterlein, 2018, January. The three pillars of virtual reality? Investigating the roles of immersion, presence, and interactivity. In Proceedings of the 51st Hawaii International Conference on System Sciences.

[5] Jerome H. Barkow, Leda Cosmides, and John Tooby. 1992. Psychological Foundations of Culture, The Adapted Mind, New YorkOxford University Press. 19-136.

[6] Henrik Peperkorn, and Andreas Mühlberger. 2013. The impact of different perceptual cues on fear and presence in virtual reality. Annual Review of Cybertherapy and Telemedicine. 75.

[7] Jonatan Hvass, Oliver Larsen, Kasper Vendelbo, Niels Nilsson, Rolf Nordahl, and Stefania Serafin. 2017. Visual realism and presence in a virtual reality game. In 3DTV Conference: The True Vision - Capture, Transmission and Display of 3D Video (3DTV-CON), Copenhagen, 2017, 1-4.

[8] Di Wu, Dongdong Weng, and Song Xue. 2016. Virtual Reality System as an affective medium to induce specific emotion: A validation study. Electronic Imaging, 1-6.

[9] Jih-Hsuan Lin Tammy. 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. 72350–361.

[10] The body VR, [online] Available: http://thebodyvr.com/.

[11] Mariko Shirai, Naoto Suzuki, 2017. Is Sadness Only One Emotion? Psychological and Physiological Responses to Sadness Induced by Two Different Situations: “Loss of Someone” and “Failure to Achieve a Goal”. Frontiers in Psychology, 8. doi:10.3389/fpsyg.2017.00288

[12] Nigel P. Field, Lisa Orsini, Roni Gavish, Wendy Packman, 2009. Role of Attachment in Response to Pet Loss. Death Studies, 18 March 2009, Vol.33(4), pp.334-355.

[13] Takashi Numata, Hiroki Sato, Yasuhiro Asa, *et al*., 2020. Achieving affective human–virtual agent communication by enabling virtual agents to imitate positive expressions. Scientific reports, Vol.10(1), pp.5977

[14] Felicia R. Baltes, Andrei C. Miu, 2014. Emotions during live music performance: Links with individual differences in empathy, visual imagery, and mood. Psychomusicology: Music, Mind, and Brain, 24(1), 58–65. https://doi.org/10.1037/pmu0000030

[15] Ira J. Roseman, Martin S. Spindel, Paul E. Jose, 1990. Appraisals of Emotion-Eliciting Events: Testing a Theory of Discrete Emotions. Journal of Personality and Social Psychology, 1990, Vol.59(5), pp.899-915.

[16] Michael Ambinder. Biofeedback in Gameplay: How Valve Measures Physiology to Enhance Gaming Experience. In Game Developers Conference, 2011.

[17] Jakob Nielsen, Rolf Molich, 1990. Heuristic evaluation of user interfaces. CHI '90: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 1990, pp.249-256.

[18] Jakob Nielsen, 1992. Finding usability problems through heuristic evaluation.. CHI '92: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 1992, pp.373-380.

[19] Cindy Harmon-Jones, Brock Bastian, Eddie Harmon-Jones, 2016. The discrete emotions questionnaire: A new tool for measuring state self-reported emotions. PloS one, 11(8), p.e0159915.

[20]Alistair Sutcliffe, Brian Gault, 2004. Heuristic evaluation of virtual reality applications. Interacting with Computers, Volume 16, Issue 4, 2004, pp. 831–849.

[21] Masahiro Mori, 1970. The uncanny valley. Energy, 7(4), 33-35.

9. Appendices

9.1. Appendix A: Risk matrix

RISK	PROBABILITY	SEVERITY	CONSEQUENCE	MITIGATION	MONITORING	MANAGMENT
Evaluation forms cannot provide adequate results to draw a conclusion.	MEDIUM	HIGH	Research question remains unanswered and further research will be required.	Evaluation forms must be extensive and provide enough detail for describing and rating the events of each experience.	Test the form ourselves and revise the form multiple times before a final form is devised.	Record data anyway, carry over relevant data to next iteration research.
Not enough evaluators to record significant data	MEDIUM	MEDIUM	Data recorded could be insignificant, and no correlation between emotion elicitation and interaction can be found.	Ensure we reach potential participants through multiple departments such as psychology and science.	Keep notice and record who has signed up for the research and follow-up with participant prior to the allocated research time to ensure candidate will arrive.	Record data anyway and find ways of interpreting such data for any correlation. Otherwise. Shift focus to AI development of project.
Unforeseen mental issue in participant during experiment	LOW	HIGH	The study will be forced to terminate, as the health of the participant is compromised.	Screening should be thorough enough that this risk is avoided. Oral confirmation post screening can help reaffirm participants state of mental health.	Observe the participant and note any anomalies in reactions compared to those who do not have mental health issues.	Observe the initial reactions of the user during experiment. Stop the experiment early if potential signs of discomfort are noticed.
Ethics application response is delayed	MEDIUM	HIGH	User research with participants cannot occur as we do not have clearance to begin studies.	Send application directly to the science department rather than starting at computer science faculty. Send application at earliest date possible.	Request updates on application request if a long time has passed since sending it.	Shift focus to AI development of project.
Software bugs that break immersion	MEDIUM	LOW	Skewed data due to a breach in immersion. Attention drawn to bugs rather than experience itself.	Properly review each environment whenever a new feature is added. Thoroughly test environments before user research begins.	Track bug fixes using project management software. Ensure persistent testing throughout development of VEs.	Upon observing a bug, depending on severity, offer to allow participant to take a break before continuing, or shift users position to an area in the VE that does not have a bug.
Software incomplete/not up to expected standard	MEDIUM	LOW	Data recorded could be insignificant due to lack of features developed.	Provide a scope that can accurately accommodate our goals and deadlines for each VE. Provide leeway for any potential threats to allocated times, ensuring proper development.	Compare progress to our deadlines on the timeline, assess and reconfigure time allocations to provide time for important features.	Reduce the scope of added interaction, as long as large portion of the experience involves interaction.
Cannot access equipment due to COVID or other	LOW	HIGH	Data and experiment would lack any significant results on if the two VEs elicit emotion successfully through interaction and AI.	No way of ensuring this does not happen; as equipment is externally controlled and COVID is also externally reliant.	Stay informed about university closures and availability of equipment leading up to the experimentation date.	Focus entirely on development of the VEs and software for future studies.
Equipment is damaged	LOW	HIGH	Depending on severity of damage, user experiments could be terminated.	Trial the participant in a test environment before the emotion VE or reaffirm that they understand how to use the VR HMD and controllers, and properly disclose the play area space before the experiment.	Observe the participants movement and control of the VR hardware.	Stop the experiment and assess damage. If not significant, continue experiments.

9.2. Appendix B: Timeline

Each block represents one week.