Simulating Fear with Virtual Reality

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***Abstract*—The ability to create virtual environments that simulate the desired response for users in virtual reality is critical to the future of VR. In order to create a successful simulation of fear in a virtual reality experience, developers should utilize non-linear sounds, scary motifs, and realistic visuals. Using a a simple VR maze game using Google Cardboard while exploiting the users senses, a successful demonstration on how to simulate fear in a virtual environment was achieved.**

***Index Terms*—Virtual Reality, Google Cardboard, Simulation, fear,**

I. Introduction

Critics argue that the fate of virtual reality for entertainment purposes is dependent on a multitude of factors, including the ability to make an enjoyable user experience. The ability to create virtual environments that simulate the desired response for users is critical to this success. The thrills of scary movies and suspenseful games have drawn more popularity, being among the top five grossing genres in 2019 [1]. Users enjoy experiencing the excitement and adrenaline rush when experiencing the horror/thriller genres, but only when they successfully simulate fear. In order for a scary virtual reality experience to be successful, the developers must simulate fear.

This paper will explore the biological and psychological process in which fear is created in Section II. Section III will discuss the methods of creating the game and section IV will present a review and conclude with a discussion in Section V.

II. Background

In order to create a successful simulation of fear in a virtual system, there needs to be a psychological understanding on how and why humans experience fear.

What is fear and how does it work?

Fear is the resulting feeling after the brain is presented with a stressful stimulus which causes a release of chemicals that then stimulate changes in the heart and muscles [2]. There are five main parts of the brain that are involved with the fear response which are pictured in Figure 1. The process begins with a stimulus whether that is a scary image, sound or unexpected touch, which then stimulates the thalamus, deciding where to send sensory data. This process then ends with the hypothalamus which activates the well known fight or flight response.

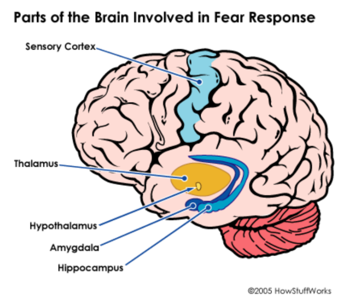

Fig. 1. Part of the Brain Involved in Fear Response [2]

What makes something scary?

Previously we have explained the process of how humans experience fear, but the underlying cause for fear also needs to be understood in order to simulate fear. As mentioned earlier, the end result of the biological process is the fight or flight response. However, there is more than just an instinctual nature that causes fear in humans. Humans also possess the ability to anticipate and formulate the idea of what might happen [3][4]. Exploiting this physiological "fear of the unknown" phenomena can be highly effective and is often a popular technique used in the entertainment industry. Research at University of Turku showed that when it came to evaluating horror movies, people were more afraid of movies that were psychological in nature and based on real events. They found that people were also more afraid of things that were unseen or implied rather than what they could actually see [3][4].

How do our senses play a role?

Exploiting the human senses play a role in how entertainment can scare viewers. Due to the nature of virtual reality and the limitation of the Google Cardboard, this paper only considers the senses of sight and hearing.

How does vision scare us?

Evolution has groomed humans to be able to quickly detect predators and objects that are unknown, and possibly even scary. Research at the University of Virginia showed evidence of enhanced visual detection of threat stimuli, such as snakes, as opposed to non-treating stimuli like a flower or a frog. Knowing that snakes are potentially harmful, we are able to quickly identify them in an image and respond quicker to the treat stimuli then with other objects. This is because of evolution that we fear certain objects and images [5]. What about monsters? Monsters and mythological creatures are also scary but are not found in nature. However, most monsters and creatures take on the characteristics of large predators or even human like characteristics that we have been pre-condition to caution.

How does sound scare us?

Similar to how our brains process ”scary” images, the human brain has also been conditioned to understand scary sounds. Years of evolution have trained the brain to fear abnormalities in sounds. Research shows that non-linear sounds invoke fear in humans [6][7]. Non-linear sounds have both high amplitude and volume when compared to other sounds. These sounds often are chaotic and noisy, with abrupt frequency jumps and irregular harmony [6][7]. Scientists believe that these sounds have been programmed into our minds as scary because of evolution. These sounds are often out of the range of human voices and trigger fear due to the abnormality of the sounds [6][7]. Hollywood and game developers use these nonlinear sounds to add to the user experience.

A successful scary virtual reality experience should utilize non-linear sounds, scary motifs, and realistic visuals.

III. Methodology

Using the background research discussed in Section II, the methodology presented in Section III demonstrates the tools used to create a fear simulation. The simulation is broken up into these main developments, utilizing previous learned fear through pop culture references, taking advantage of the psychological fear of the unknown while also exploiting the users senses. Section IV discusses the technical details. Section V serves as a discussion of the development and Section VI will sum up concluding thoughts.

This game and experiment was designed using a Google Cardboard and Unity. The task is a simple maze, with only one solution, as shown in Figure 2.

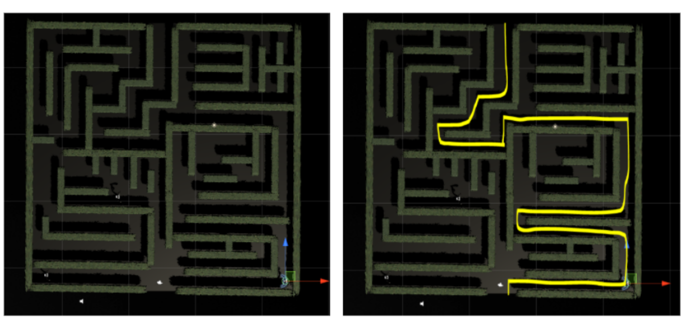

Fig. 2. Maze and Solution

Fear of the Unknown

The game utilizes the human fear of the unknown in two ways; 1) the game is a maze, the outcome of every decision from the user is unknown and 2) the users are given no indication that the game is structured for fear. The users are simply asked to put on the head set and to accomplish the goal of getting through the maze.

User Senses

The game is designed to exploit the user’s senses in a variety of ways, focusing on only what the user hears and sees. This game was designed to work with google cardboard, therefore user touch was ignored.

User Sight: The game is designed to be spooky, therefore large dark hedges were used to design the maze and produce strong shadows as well as a dark skybox. Figure 3 shows the opening scene of the simulation. The scene is intentionally dark to play on a natural instinct to be cautious or fearful of the dark. The use of the tall hedges make it so the user is unable to see over the maze, and exploits the fear of the unknown.

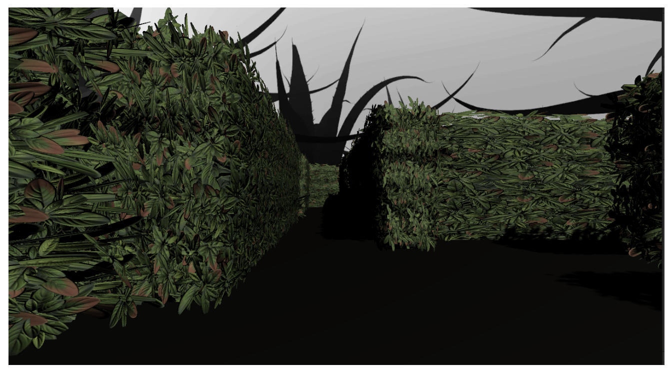

Fig. 3. Opening Scene

When the user tilts their head down 30 degrees, they begin moving through the maze, intentionally, multiple NashMesh agents (we will refer to these as enemies) are placed throughout the game as a fear stimulus to the user. A visual of the enemy can be seen in Figure 4. These NavMesh agents take on the look of SlenderMan, a popular pop-culture character. Slenderman is successful in instilling fear because the character resembles human-like characteristics. The character is tall, with unrealistic long arms and legs. The user can identify that this character isn’t human, but close to it, this is a exploitation on a common to phenomenon in which humans get suspicious and cautious by humanoids.

There are two main types of placements of the enemies, visual placement and a hidden placement. Figure 5 shows the difference of these placements.

The visual placement means that the enemy is intentionally placed in plain sight. This placement purpose is designed to draw out anticipation and curiosity in the user to move closer to the unknown figure. Hidden placements mean the enemy is intentionally placed behind a corner where the user can not easily see the enemy but will stumble upon the enemy accidentally. This purpose is designed to trigger a jump scare.

Animation of the enemy is also designed to be creepy. Figure 6 shows the state transitions for the enemy. Upon

Fig. 4. Enemy Character : Slenderman

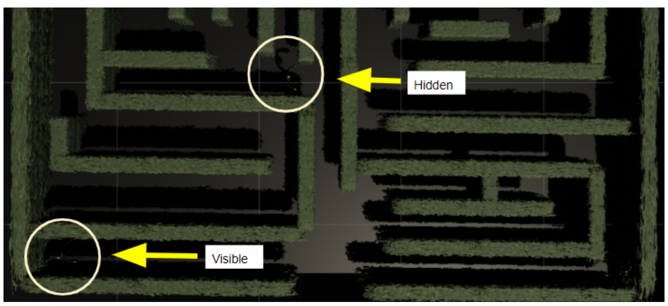

Fig. 5. Placement of NavMesh Agents. Hidden agent (top), visible agent (bottom)

entering the game, the enemy walks and idles, adding to a creepy unknown behavior. The user, either by curiosity or surprise will walk near the enemy. After the distance of the user and the enemy are within a threshold the animation changes and the enemy then screams at the user and attacks. As the user runs away the enemy will chase towards the player until the player is no longer in sight, in which the animation returns back to the walking state.

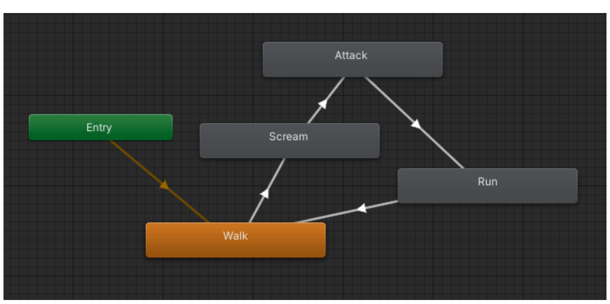

Fig. 6. Enemy Transition State Machine

User Hearing: The choice of music really sets the ambiance for the game. Using a scary effects sound clip, the user immediately enters the simulation noticing that not only is the game visually dark, but it sounds spooky. Jump scares are important to any horror game or movie, so the enemy was given a sound that is triggered when the player comes within a distance threshold of the enemy player. Looking at Figure 7. we see the comparison between the artificial scream and the scream from a human. The artificial scream has a higher frequency and is louder than the human scream adding to a non-linear sound environment to better trigger a jump scare.

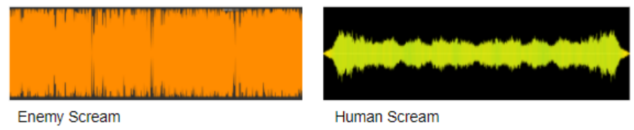

Fig. 7. Comparison of a Human Scream to the Artificial Monster Scream

Movement

The simulation was designed using only the Google Cardboard, therefore there are limitations on how to move about the simulation. The Cardboard is constrained to a touch interaction via a button on the top of the cardboard that taps the users device or the ability to use gazing. Two different designs were considered and tested during development. The first was a click to move functionality, the second utilized a gazing direction to move. If the user tilts their head down at 30 degrees than the user would be able to run in a certain direction to explore the maze.

IV. Technical Details

The simulation main goal is to exploit the senses and psychological nature of the user, therefore a majority of this paper focuses on the development of this exploitation, however technical details must be discussed. The simulation was developed using Unity, with a Google Cardboard using an Android phone. The technical details have been divided into the following subsections; the scene, the player, the enemy, and the audio.

The Scene

The scene is a composed of just three elements, a cube stretched to serve as the ground, a hedge and a skybox. The hedge and the skybox were both downloaded from the Unity store. The maze is constructed out of many different individual hedges. Currently there is only one scene and one maze. The maze was created by hand and then implemented on Unity by a copy-and-paste method of individual hedges that were resized and reoriented to create the structure of the maze. The colors of both the floor and the hedges are intentionally dark to set an eerie mood. The skybox is a mixture of white and black, to provide light so the simulation isn't too dark.

The Player

The player is simply a rigid body with a capsule collider and an attached camera. The players character controls as mentioned earlier are simple. All the character can do it the simulation is walk and look around the scene. There are no other interactions with the scene. The player speed can be modified in the controller settings, however, consideration to the most comfortable speed was considered.

The Enemy

The enemy is a Slenderman character which was downloaded from the Unity Store. There are multiple enemies throughout the maze and they have been created as a NavMesh Agent so they may move across the maze while also not walking through hedges. The controls for the enemy are more complicated than that of the player. The enemies either idle or walk about the maze until the player comes into a threshold range. Once that range is met, the enemy transitions into the different states as discussed earlier.

The Audio

The audio is from a StudioX download from the Unity store. The audio is placed in the scene and plays in a loop to cause constant chills. The scream from the enemy is an additional audio that interrupts the main audio when triggered. The sound also only follows a distance range with the enemy. If the user in the situation moves to far away from the enemy, the sound can no longer be heard.

V. Discussion and Evaluation

Ideally the best way to measure how successful the simulation was is to measure the heart rate of users. This technique is popular, it uses an Electrocardiogram (ECG) to record the electrical signals from the heart. This technique was used to analyze the scariest movie, but without the use of an ECG to measure heart rate, the only way to measure the success of fear simulation is to rely on feedback from the simulation testers. Due to COVID-19 Pandemic the user tests for this experiment were constrained to two testers, who happened to be roommates of the author. As mentioned in the previous section, the users were not told that they were playing a game that was scary, but instead directed that they needed to exit the maze. The users determined upon entering the game that it was scary based on the sounds and the look of the atmosphere. For each tester, the type of "scare" was controlled. The first user was instructed to follow a path in which the enemy was intentionally placed in sight. The user responded with nervous laughter and used phrases such as "that was scary" and "how do I get out of here", both demonstrating the flight or flight reaction. The second user was instructed to follow a path that led to a hidden enemy in order to simulate a jump scare. The user responded with a startled jump. Both users agreed that the sound itself added more to the scary environment than the imagery.

The Combination of Senses

One important observation about the simulation is the connection of the users senses. Without one or the other, the simulation is no longer scary. If the user begins the simulation and only has visuals, the experience is no longer spooky, but instead just a simple maze with a random character. The same is true for the other scenario in which the user just experiences noise. In order for the fear simulation to be successful, the VR simulation must include both sound and imagery to be effective. For this simulation, the senses that could be exploited was limited to just sight and sound because the simulation is done with a Google Cardboard. However, other simulations might be even more effective if able to simulate fear with other senses such as the users sense of touch and smell. Utilizing all user senses could make the virtual experiences more realistic and more frightening.

Motion Sickness

As mentioned in previous sections, understanding how to optimize user experience with movement, and lighting was also explored. The users were asked to test a variation of the simulation, where instead of looking down at 30 degrees to move, the users would press the button on top of the google cardboard in order to move one step. The users both commented that this took away from the "realistic" movement and made them feel sick. These comments were expected, because naturally we don't think "click to walk", we just do it automatically. The ability to move throughout the simulation more naturally makes the user experience more enjoyable.

The speed in which the user moves around the simulation was also considered. It was found that if the user moved two slow, then the cartoon-like nature of the VR experience becomes more apparent and makes the user feel sick. If the speed of movement is too fast, then the user is also sick, it becomes harder to navigate, and the user cannot see the details of the simulation which makes it less of a realistic experience. In order to facilitate a realistic experience while reducing the risks of motion sickness, both how the user interacts with motion and the speed in which the user moves should be considered. It was found that in this application the best way to simulate a quality experience was to use a medium-to-slow speed while having the loser look down to move.

Future Work

The long term goal of this project is to turn the simulation into a series of different scare simulations. In the future there will be different characters and motifs that the user can choose from to stimulate a fear response specific to the user. For example, another scene could involve clowns or spiders, or fear of heights. Incentive and punishment would be good additions to the simulation, a game like style. Currently there is no punishment for being constantly attacked by the enemy. In a future development of the simulation, the user should display a health bar and take attack and have that be represented visually, and eventually die. Similarly, the users should be rewarded with points for surviving for a prolonged

Fig. 8. Users Testing the Game

period of time, and the level of fear intensity should increase. Another issue with the simulation is there is only one level and the maze is static. A future implementation could be to add multiple levels and more interaction in each scene. Finally, having more users to test the game would be beneficial for feedback, and even using an ECG to measure the heart rate while the users play would give better insights to the experience.

Ethical Responsibility

Seeking thrills and getting scared can be fun, but it can also have a negative effect on the psychological state of the user. Developers must pay attention to the ethical implications and potential dangers of any software developed. Therefore in current and future development of VR horror thrills, it's important to check in with the user (in simulation) to remind them that what they are seeing is not reality. It's also important to give a disclaimer before hand, warning users of the nature of the game.

VI. Conclusion

This experiment demonstrates how to simulate fear in a virtual environment however, a lot can be done in order to perfect the experience. Using a Google Cardboard, the simulation demonstrated the importance of sound and visuals for successful creating the virtual experience. As discussed earlier, without the use of sound, the simulation may not generate scares. There is a lot of work that can be done in this domain, and a lot of deeper studies that could include research on how to optimize these fearful experiences, but also the long and short term psychological side effects users experience from these virtual realities. This research combined with other domains may even be able to help study Post Traumatic Stress Disorder patients and help them face and overcome traumatic experiences in a ”safer” simulation. The biggest take away from this simulation is that simulating fear can be done with the simplest of tools, which opens up an exciting future for virtual reality in this domain.

VII. Acknowledgements

Special thanks to Jess and Ryan for helping test out the simulation.

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