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Virtual Acoustic Ecology of Fear: An Evaluation of a Hypothetical Framework

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Abstract

The effects of sound are psychological, physiological, cognitive and behavioural. Exploring the relationships between sound and the player in virtual worlds can benefit audio designers by communicating expressive and immersive audio experiences. Acoustic ecology is becoming an increasingly important area of interest within the field of game audio research. The concept of a virtual acoustic ecology has arisen from past literature which seeks to chart the interrelationships between player, the sound and the virtual environment. A bespoke video game was developed to investigate the interactions between audio stimuli and emotional response. Using a hypothetical framework of the Virtual Acoustic Ecology of Fear as a guide to understanding the web of interactive sonic relationships in video game ecology. From the results of this research, it is suggested that the perceived characteristics of a sound decide the cognitive direction of a fearful experience, simultaneously priming the player for appropriate emotion and behaviour in response to auditory stimuli. These findings suggest the importance of applying the concept of virtual acoustic ecology to audio design, to enhance the understanding of the relationships between sound, player and virtual environments.

Keywords: Virtual acoustic ecology, emotion, perception, fear

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Affective sound is an important component of processing information, interpreting emotions, and deciding behaviour (Frühholz, Trost, & Kotz, 2016). This study ultimately concerns itself with the relationship players have with sound, and the consequence of interacting with that sound in the game world (Collins, 2013); more specifically, the relationship between players and sound in response to a fearful experience.

Acoustic ecology (Schafer, 1977), virtual acoustic ecology (Grimshaw and Schott, 2008) and the Virtual Acoustic Ecology of Fear (VAEoF) hypothetical framework proposed by Garner (2013) are the main concepts that will be explored. This framework outlines the interactions and processes between the player, sound and environment that occur during gameplay; which, in turn, can then be utilised to manipulate the cognitive direction of a fearful experience through sonic interaction.

So far, no previous study has put this hypothetical framework to practice (T. Garner, personal communication, May 4, 2020); therefore, there is no reliable evidence that such a framework will work under the reality of implementation. The aim of this study has therefore been an attempt to establish whether the framework would be successful in priming the individual for the appropriate behaviour and emotional response to auditory stimuli. Consequently, contributing to the growing area of virtual acoustic ecology research to advance our knowledge of game audio through interdisciplinary research. Throughout this dissertation, the term ‘VAEoF’ will refer to the Virtual Acoustic Ecology of Fear model.

The main questions addressed in this study are:

Do (and how do) the perceived characteristics of a sound have the ability to influence emotion and behaviour?

Does the VAEoF contribute to game audio design?

Is it possible with such a model to predict the action and response of a player?

Acoustic Ecology

Founded by Schafer (1977), acoustic ecology incorporates science, society and arts to sound studies. Explaining the attempt to unify these research areas, Schafer (1977) proposes that the interpretation of sound, the effect on behaviour, and how a person can compose the soundscape around them can lay foundations down for a new interdisciplinary approach. The involvement of virtual worlds is unmentioned by Schafer (1977), although it is believed that factors and priorities of acoustic ecology could help explain game audio concepts and designs (Alves & Roque, 2011)

Methods of research in soundscape studies have been seen as difficult to distinguish soundscape factors and the relationship between the environment and human experience because soundscapes are seen as a subjective experience (Davies et al., 2013). Due to this, there has been some thought on the reassertion of the practice of acoustic ecology. An article by Paine (2017) displays the concern that the term soundscape is over generalised due to a fractured community working under separate broad practice titles. This study argues that community engagement, well-being and social cohesion should be the priorities of the research under acoustic ecology. Interestingly, as this standardisation is yet to be laid down, it proposes the questions to where other similar research that does not fall directly under the category of Paine's (2017) acoustic ecology stand; such areas that research soundscapes out of the context of health and well being, for example, the acoustic ecology of games.

Acoustic Ecology of First-Person Shooters

The first serious discussions of the concept of a virtual acoustic ecology were relayed by Grimshaw (2007). This research has focused on how the first-person shooters (FPS) acoustic ecology attempts to emulate real-world ecologies and see players as vital components in the construction and maintenance of the soundscape (Grimshaw, 2007). The thesis suggests that game audio can be conceptualised as an acoustic ecology and a way of understanding virtual sonic relationships. Grimshaw & Garner (2014) propose an updated version of this model called the Embodied Virtual Acoustic Ecology (eVAE). This includes the concept of embodied cognition with game sound and seeks to organise associated variables of the perceived acoustic data. This research seeks to distinguish the relationships between player, sound and virtual environment and acts as a framework for understanding player's perception of sound.

Acoustic Community of the Game World

The concept of an acoustic community was developed by Barry Truax (2001) and is coupled and inspired by Schafer's (1977) theory of acoustic ecology. This model signifies that sound plays an

important role in the lives of its inhabitants by keeping them in touch with events within it. Sound events hold semantic information to those who are within the community and allows them to define individual and community lifestyles. This implies the player's understanding of the game environment in relation to sound, with a focus on how sound functions within the game community depending on social and environmental events. This concept applies greatly to multiplayer games in which players interact and communicate with each other rather than human-computer interaction (See Appendix A for further information on the acoustic community).

Game Design

The *Acoustic Design* chapter in *The Tuning of the World* by Schafer (1977), explains that people are responsible for the balance, construction and maintenance of the surrounding soundscape. This can be seen as similar to how game and sound designers are responsible for developing balance within virtual worlds. In Grimshaw & Schott's (2008) conceptual framework model, the inclusion of the game engine resembles the decisions made by the sound designer. It is possible for the acoustic designers of a virtual world to influence how sound is perceived by players; deliberate decisions are made to express meaning through sound, to either increase immersion or communicate to the player through audio signals.

Spatial Audio

Spatial audio delivers accurate spatialisation and real-time interactive sonic elements (Murphy & Neff, 2010). This is an important factor for the spatial awareness of the player and their understanding of the surrounding environment. Usual sonic features that are established in spatial audio tools such as Resonance Audio (Google, 2018), assist in emphasising these relationships.

In terms of acoustic communication theory, spatial audio can be seen as a clearer way of understanding and communicating an acoustic language in games compared to listening through stereo or surround sound. The features allow for a more dynamically detailed listening experience which allows greater possibilities of presenting new player interrelations to their environment and other players. The significant increase in immersion spatial audio can provide to players supports Grimshaw's (2007) idea that the more immersive a game is, the more appropriate it is to discuss the game world as an ecology.

Diegesis

The terms diegetic and non-diegetic were originally used within film theory to examine the use of sound in cinema. Film theorists such as Michel Chion (1994) used these terms to categorise sound and to separate sound between the film world from the real world.

Grimshaw (2007) presents the terms ideodiegetic and telediegetic to explain game-specific terminology for the relationship between diegetic and non-diegetic sounds. Ideodiegetic can be seen as the sounds heard by the player, such as triggered sounds from the player's actions (kinediegetic), and ambient sounds from the environment (exodiegetic). Telediegetic sounds are what the player cannot hear around their location but maybe heard by other players, thus holding relevance for a method of behaviour (See Appendix B for further information on diegesis).

In terms of a virtual acoustic ecology, it is important that the perspective is listened through the auditory position of the player's avatar regardless of diegetic/nondiegetic sound (See Appendix C for further information on listening positions). The game soundscape as a whole conveys information towards players in many ways. Although whilst there has been some reassertion of previous models, there has been no standardisation of the taxonomy of diegesis and perspectives within games; as hinted by the title of Jørgensen's (2011) paper *Time for New Terminology?*.

Psychology of Fear

A mention of psychology, perception and cognition is an essential role in understanding the relationships between players, sounds and the environment. The psychology of sound and fear within virtual worlds, the role of interactive sound to describe game sound ecology phenomena will be analysed.

Fear and Audio in Games

Emotion has been known to play a key part in delivering immersive game audio. Through expressive soundtracks or audio signals, sound has become a way for audio designers to directly communicate to the player. Perron (2005) states that emotions arise from the interactions of the player, these are named gameplay emotions. By examining these emotions by giving examples of game situations, he exemplifies how single-player gameplay scenarios can instigate emotional responses which in turn have action tendencies (See Appendix C for further information on emotion and interactivity). By this emotional manipulation, players within this immersive environment associate themselves with the player avatar, therefore a threat to the player avatar is a threat to the player (Garner, Grimshaw, & Nabi, 2010).

Emotion is commonly expressed through music in games. Although, Grimshaw (2007) states in his thesis that music may arguably be viewed as part of the acoustic ecology, but is mostly concerned about gameplay sounds. Västfjäll (2012) presents a study on the emotional reactions to sounds without

meaning (static, tone and noise) and finds that pleasantness-unpleasantness were governed on perceived loudness and arousal by the perceived sharpness of the sound. The effect of everyday sounds on emotion within virtual worlds is not defined clearly in detail to a specific emotion, although it is assumed that humans can gather some form of meaning from a perceived sound without attached emotions.

Virtual Acoustic Ecology of Fear

The aim of this research is to manipulate a player's emotional response to sound using the VAEoF (Garner 2013). This model represents four stages of fear built around the defensive behaviour system by Fanselow (1994). Garner (2013) integrates audio classifications into the framework which works as a theoretical guide to seek the manipulation of a player's fear response through suggested audio characteristics.

Safe Stage

During this stage, the player is removed from the threat. The audio is supposed to portray safety and relief. The autonomic nervous system (ANS) steadily adjusts the normal physiological state of the player and consequently retrospects on the fear event.

Caution Stage

This is the Pre-Encounter Defence stage in which the somatic nervous system (SNS) alerts the player to cautiously scan the environment with careful movements. The audio is to represent a suggestive future orientated threat. There is decreased heart rate and modulated respiration in the ANS and the player has focussed attention.

Terror Stage

The Terror stage represents the Post-Encounter Defence stage in which the player is remaining under local threat with higher intensity. The audio exemplifies this through closing the distance between the player but not an immediately close audio scenario. The SNS induces the player to startle or freeze and the ANS sees similar changes, although with fixed attention to the threat rather than focussed attention.

Horror Stage

The Circa-Strike Defence stage is designed to put the player under immediate threat of attack. The audio demonstrates this by succeeding to close the distance with the player with a higher intensity immediate threat. The SNS produces a reaction of startle and fight or flight response in which ANS increases heart rate and respiration.

Biofeedback

The concept of biofeedback within this study is to use the psychophysiological data of the player in order to provide an adaptive gaming experience. Not only has biofeedback been used for fearful experiences (Flying Mollusk, 2015), it has also been used for balance training (Hung et al., 2016) and teaching relaxation techniques for children with attention deficit hyperactivity disorder (Amon & Campbell, 2008). Kuikkaniemi et al., (2010) recommends to explore explicit biofeedback conditions in commercial games. The addition of clearly detailed biofeedback interaction has positively affected player experience and immersion.

Garner (2016) discusses the idea of applying biometrics and how this could also improve the artificial intelligence of non-player characters with emotional intelligence. This would add new possibilities for game mechanics, consequently opening a range of wider, more adaptive forms of audio interaction that responds to the emotional state of the player. If this technology was to become commonly available in commercial games, the potential for player immersion would increase. Therefore, it is possible that the sonic web of interrelationships between player, sound and environment would become complex, providing emotionally driven adaptive audio experiences.

Methodology

The objective is to implement and assess the VAEoF (Garner 2013) to game audio design; evaluating the interactions between audio stimuli and emotional response towards each of the four stages of fear.

Garner (2013) proposes from his theory that the perceived characteristics of a sound placed within a situational context decide the cognitive direction of a fearful experience. Therefore, the intention of this experiment is to use the theoretical frameworks provided by Garner (2013) to develop a video game experiment with the aim to prime the individual for the appropriate behaviour and emotional response to auditory stimuli.

An interview was conducted with Dr Tom Alexander Garner to assess the methods used in this study including an overall discussion of the topic. Throughout this dissertation, the researcher will include relevant information of this interview in the appropriate places.

Game Design

In order to test the VAEoF, a bespoke first-person shooter level was created called *Sosban Fach*.

Due to this study researching the emotional response to audio, the game design was developed with minimal changes in visual material. When the player finishes the first lap, they have seen all the visual material in the game, meaning there are no changes in what they see in the upcoming laps, only changes in audio. There were considerations for an audio-only game, although it was decided against due to the argument that auditory and visual cues for navigation work better together rather than by themselves (Lokki & Grohn, 2005). Therefore, the level design takes inspiration from the unreleased game titled *P.T.* (Kojima Productions, 2014) in which the player is trapped within two corridors which consequently loop back on themselves. This design was decided to minimise the impact of visual material on the level of horror so that emotional response was only determined by audio as much as possible (See Appendix C for visual game design details).

Garner asserted that the game design falls in the category of walking simulator games (T. Garner, personal communication, May 4, 2020). There is evidently a focus on narrative experience rather than game mechanics and replay value (Zimmerman & Huberts, 2019), which compliments the intention of this project.

Audio Design

The game uses the Oculus Spatialiser as an audio plugin to supply an improved three-dimensional (3D) audio spatialisation, producing a key part in providing presence in applications (Oculus, 2020). Using the Oculus plugin affords real-time reverb and occlusion which allows sounds to be propagated in a way that seems to originate and move realistically through the virtual environment. Not only does spatial audio provide a more immersive experience, it also allows the sound designer to communicate more information to the player (Broderick, Duggan, & Redfern, 2018).

The sounds developed for the game are meant to elicit the player reaching each stage of fear. The parameters such as tempo, pitch, distortion, attack, sharpness and reverb played a role in developing sound events to induce the four stages. However, Garner, Grimshaw, & Nabi, 2010 discovered that not only acoustic parameters are key to effective fear manipulation, the sounds must be placed within a context in which the player can attach semantic meaning to the situation at hand (See Appendix D for examples of placing sound in context). It is also important to note the use of three audio files from *P.T.* (Kojima Productions, 2014), which included the radio and two female voice takes of cries and laughter. The decision to use audio from pre-existing titles assisted in setting a story for this research project.

Data Collection

At the time of this study, it was impossible to gather participants together to conduct the experiment. The research would also not be able to collect electrocardiogram (ECG) data to interpret the physiological effects of the participant. Therefore, the data is being collected through a questionnaire on google forms which allows this experiment to be administered online. Though it is recognised that questionnaire response rates may be low using this method (Denscombe, 2011), it is also quicker and easier to collect responses through automated data input (Walliman, 2010). More importantly, the absence of the researcher assists relieving the possibility of white coat syndrome in which the participant may feel obligated to act in a certain way. A Discord server (Discord, 2015) was created to allow participants to easily ask questions, communicate with the researcher and more importantly, provide feedback of the experience.

Participants are required to complete a pre questionnaire which includes age, gender and to state their experience in video games; including their experience specifically in FPS and horror games. By gathering this information it is possible to compare results from participants with a different range of video game experience. It is hypothesised that participants with more horror game experience may find the game less frightening than participants with lesser experience.

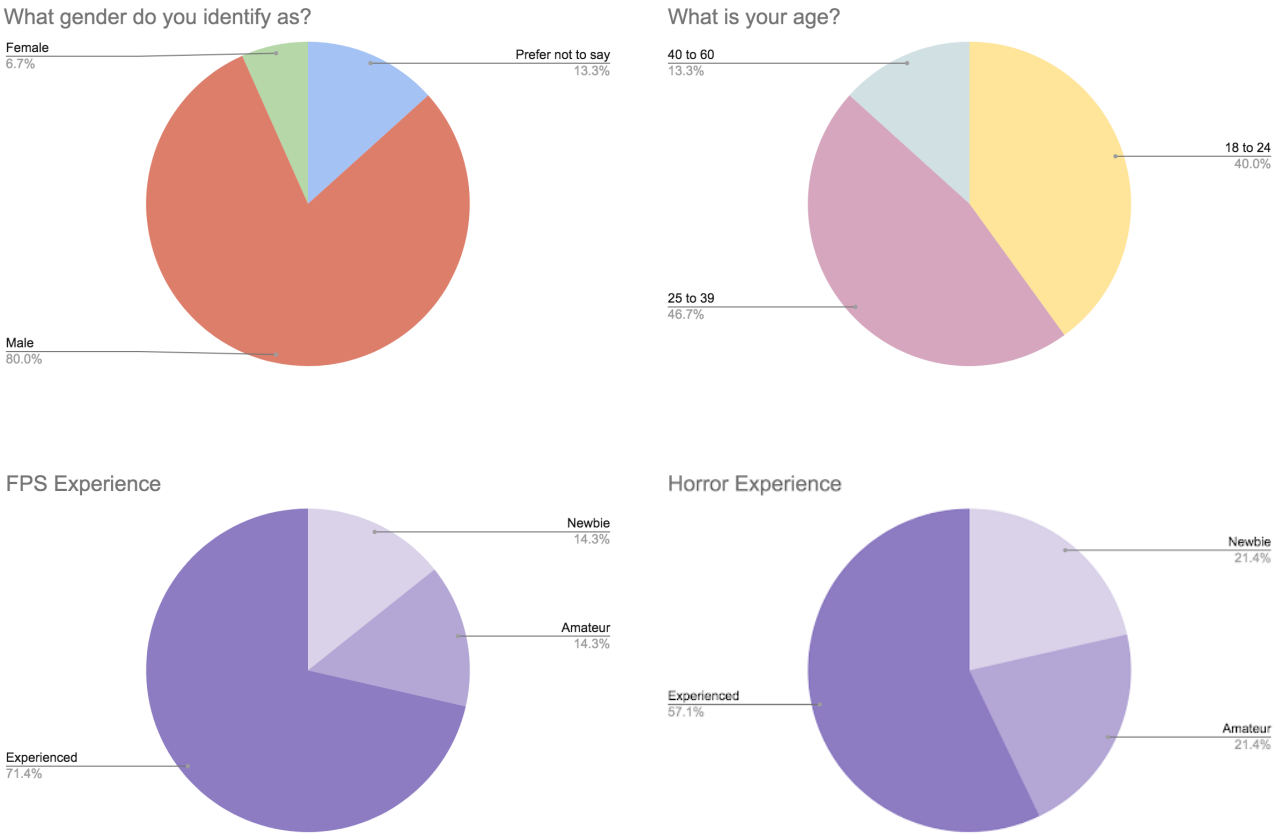
Once the participants have completed the game, they are required to answer the same set of four questions for each lap in the form of a four point semantic differential scale. This method was chosen to assess the strength of feeling by asking a participant how often they felt a certain way (Thomas, 2017). A four point scale was decided to drive participants' decision to choose either side, being unable to choose a middle point. The questions are meant to discover if a participant has experienced a certain stage of fear in a lap. The questionnaire was given after the participant completed the game in order to avoid breaking immersion and flow during playthrough. Although due to this, participants may not be able to remember what happened in each lap. Therefore the questionnaire asked one general question relating to each of the four stages of fear to minimise the problem of memory (Bell & Waters, 2014). A short Game Experience Questionnaire (GEQ) was given after the main questionnaire to gather information on immersion, difficulty, scariness, intensity, emotion and performance. Additionally, the GEQ asked open-ended questions in order to allow participants to elaborate on points of interest (Denscombe, 2011). Garner stated that he had no major criticism on the data collection methods used in this study and that the questions asked would likely receive the desired results (T. Garner, personal communication, May 4, 2020).

Participants and Ethics

15 participants (12 male, two prefer not to say and one female) were gathered through online gaming and audio forums. There were six participants aged between 18-24y/o, seven aged between 25-39y/o and two aged 40-60y/o. Participants rated their experience on playing video games from one to ten and the mean score was 7.9 with all stating that they were familiar with mouse and keyboard controls. On a scale of one to three, participants rated their experience in FPS and Horror games, a mean score of 2.6 in FPS and 2.4 in horror experience.

Figure 1

Pre-Questionnaire Results



The participants were told in the brief before the pre-questionnaire that the aim of this experiment was to explore the emotional responses to sound within a game environment. The participants were also instructed on how the game is designed with four laps and instructions on how and when to answer the post questionnaire. Before continuing to the pre-questionnaire participants are required to sign a

disclaimer. Each individual was made aware that the game may be perceived as frightening or upsetting and by continuing beyond that first page they are agreeing to proceed with the experiment.

Procedure

Due to the time in which this research was conducted, it was impossible to gather participants in a single area due to COVID-19. This posed some major changes in how this experiment was to be conducted.

Instead of having a single PC in which the game would be used for the experiment, the procedure had to be optimised for participants to conduct this experiment in their own homes with their own computers. Unfortunately due to this, a few implications rose.

It became difficult in finding a solution to measure heart rate to gather unbiased information on each participant's experience. Therefore, in addition to the gameplay questionnaire, a short game experience questionnaire was added to the end to gather information on immersion, difficulty and performance including an opportunity to describe the most memorable and intense section of the game.

The same equipment is not guaranteed therefore the performance of the game varies between participants. Extra care was taken in optimising the game as much as possible to ensure the experience was delivered as expected. To combat this, the quality settings were set to the lowest possible in favour of performance, playability and flow rather than better graphics quality; this may affect the amount of immersion and believability.

In light of these implications, the researcher had to conduct the experiment in field and natural conditions. The participants may feel more relaxed when in the comfort of their own home and there is less probability of demand characteristics that influence the results (Walliman, 2010). However, there is more chance of distraction. Therefore, participants are advised to feel relaxed before starting and to complete the experiment with as little distraction as possible.

Preliminary Testing

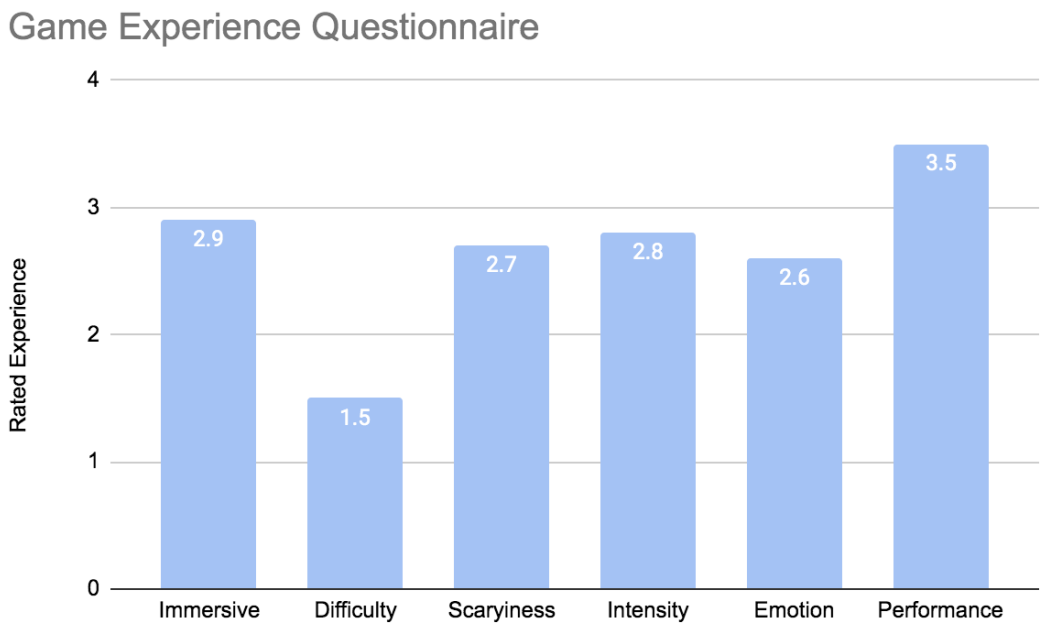
Although the game performs without any issues on the computer it was developed on, it is safe to assume that there will be some complications on running it on other computers. The intention of conducting a series of tests before the release of the experiment was to remove these possible problems that would make it an issue in delivering an effective experience for the participant. A post was sent out online to collect volunteers to test the performance and playability of the game on different computer

specifications. Volunteers included students, friends and family members. (See Appendix E for feedback and changes).

Results

Figure 2

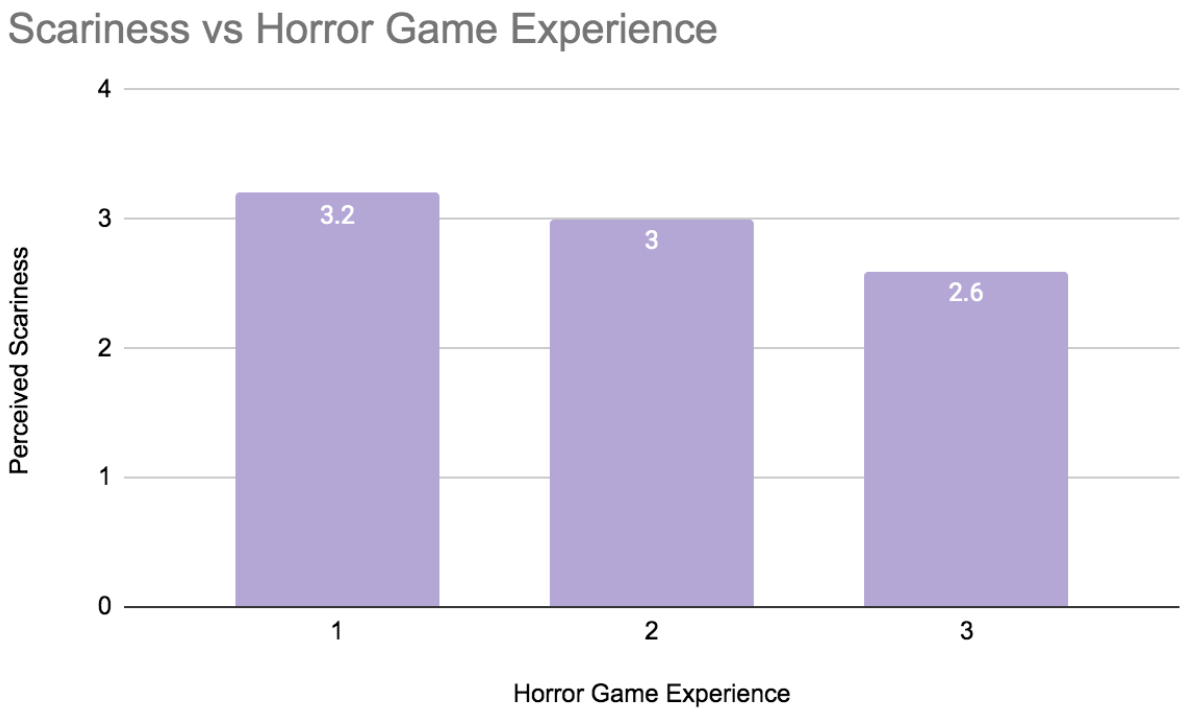
Game Experience Questionnaire



Note. The mean scores are shown in this graph of the rated game experience of the participant.

Figure 3

Scariness vs Horror Game Experience



Note. There was a total decrease of 15% perceived scariness from newbie (1) to experienced (3) horror game participants. The mean score was 2.9 with a standard deviation of 0.3.

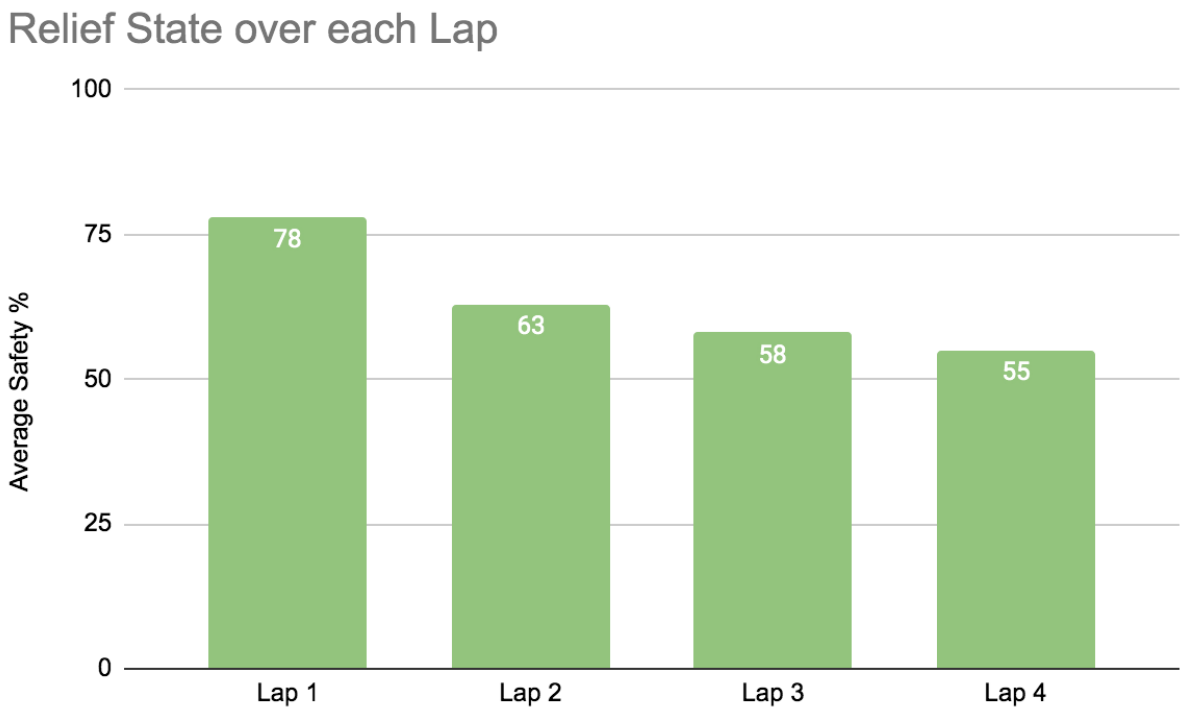
Figure 4

Presence vs Horror Game Experience

Note. There was a total decrease of 20% perceived involvement from newbie (1) to experienced (3) horror game participants. The mean score was 2.9 with a standard deviation of 0.4.

Figure 5

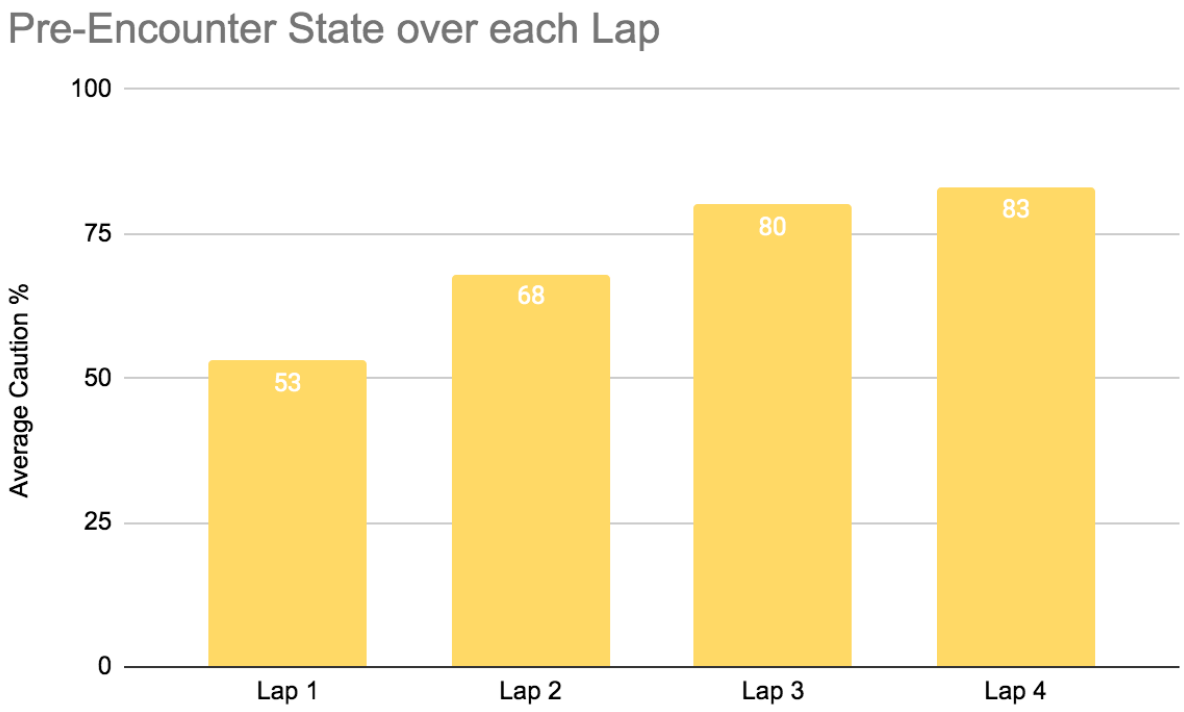
Relief



Note. Results from the Relief State show a total decrease of 23% perceived safety from Lap 1 to 4. The average scored for safety was 2.5, with a standard deviation of 0.4. Both median and mode scored a 2. A T-test was performed to compare results from the Relief State in Lap 1 and Lap 4. There was a significant difference in the score in Lap 1 (M=3.1, SD=1.09) and Lap 4 (M=2.2, SD=1.14) in which the probability value was 0.04.

Figure 6

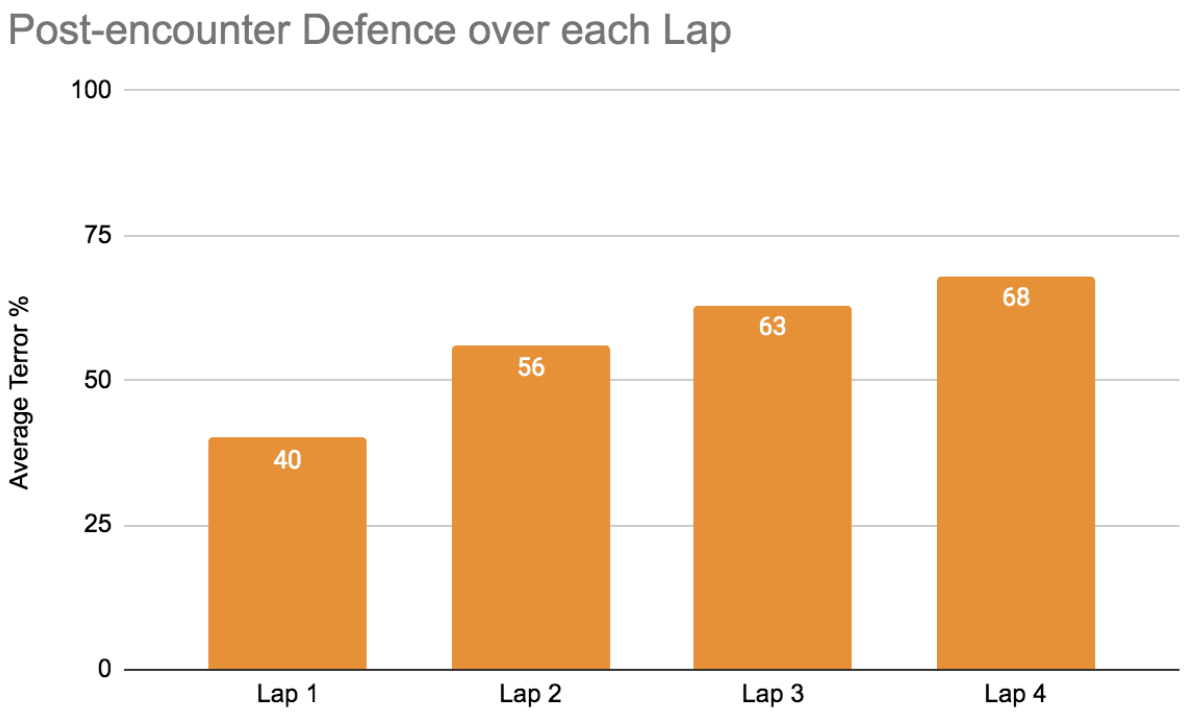
Pre-Encounter Defence



Note. There was a total increase of 30% perceived caution from Lap 1 to 4. Mean scored a 2.8 on caution with a standard deviation of 0.55. The median scored a 3 and mode scored a 4. There was a significant difference in the caution in Lap 1 (M=2.1, SD=1.06) and Lap 4 (M=3.3, SD=0.97) in which the probability value for the T-test was 0.004.

Figure 7

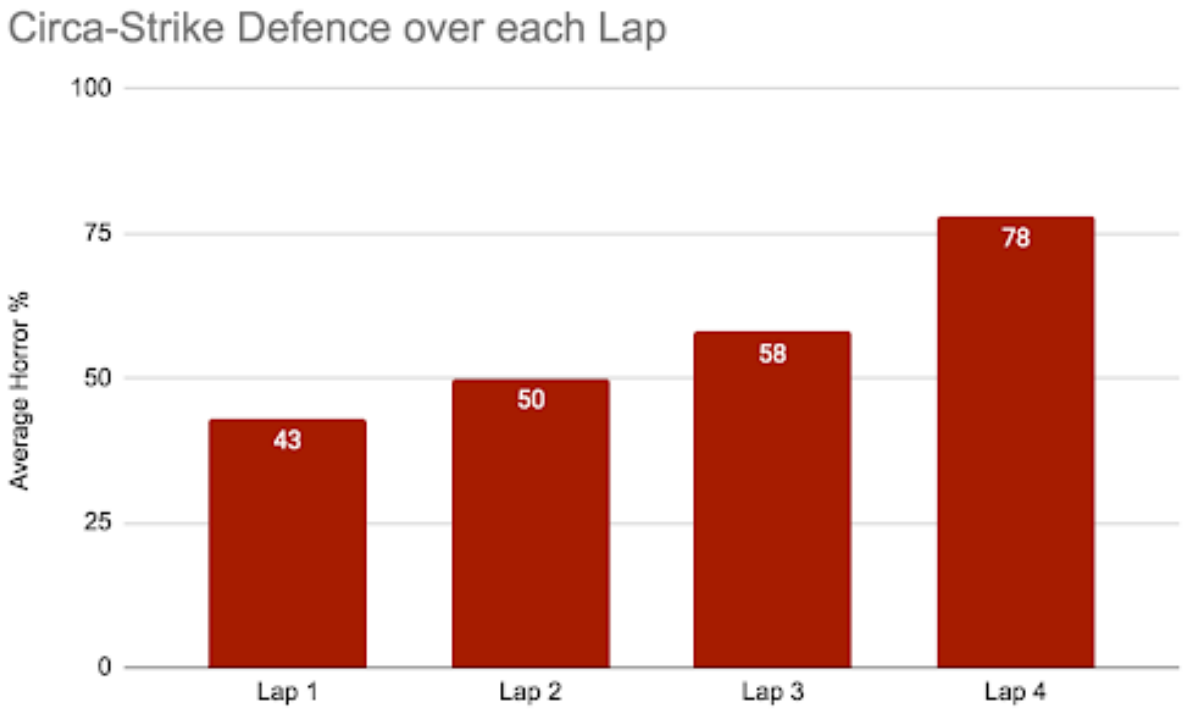
Post-Encounter Defence



Note. The perceived terror had a total increase of 28% from Lap 1 to 4. The mean scored a 2.3 with a standard deviation of 0.47. The median was 2 and the mode was 1. There was a significant difference in the terror in Lap 1 (M=1.6, SD=1.05) and Lap 4 (M=2.7, SD=1.04) in which the probability value for the T-test was 0.006.

Figure 8

Circa-Strike Defence



Note. Perceived horror had a total increase of 35% from Lap 1 to 4. Mean scored a 2.3 with a standard deviation of 0.6. The median was 2 and the mode was 1. There was a significant difference in the terror in Lap 1 (M=1.7, SD=0.89) and Lap 4 (M=3.1, SD=1.09) in which the probability value for the T-test was 0.0009. In relation to all above-mentioned T-test's, the probability value states that there is a 95% confidence value that the results are significantly different.

Discussion

This study has used the VAEoF as a guideline to assess the interactions between audio stimuli and player responses to the four stages of fear. In the experiment, fifteen participants played a horror experience in which they were asked questions on their perceived state of fear.

Firstly, the results obtained from the GEQ revealed that participants found the experience immersive (M=2.9). Feedback gathered that visual aspects might have had a negative effect on the immersion, although audio had a positive immersive effect. As mentioned in the literature review, Grimshaw (2007) states that the more immersive a game is, the more appropriate it is to discuss it as an ecology. The result implies that it is possible to discuss this experience as an acoustic ecology, although, ideally this number would be higher.

Additionally, some participants found the experience difficult (M=1.5). Reports in the feedback suggest that brightness was too low which affected the ability to navigate around the kitchen and living room. Although despite the experiment being conducted in field and natural conditions, the performance (M=3.5) of the game was high.

Participants found the game to be scary (M=2.7) and intense (M=2.8), both variables were put together to obtain the perceived scariness. In addition, emotion (M=2.6) and immersion (M=2.9) were put together to acquire a perceived sense of presence. The relationship identified between both variables and horror game experience revealed that less experienced players were more susceptible to fear manipulation and were more likely to be involved in the experience. It seems possible that these results are due to the amount of familiarity players have in fearful gaming scenarios in which they are more in control and aware of their actions.

The state of relief decreased through each lap. Though the level of perceived safety had the largest decrease from Lap 1 to 2. This observed decrease could be owed to the fact that nothing in Lap 1 was meant to be perceived as very scary. Although this does indicate that the sudden events of Lap 2 lowered the confidence of the participant the most. Beyond Lap 2, the level of safety slowly decreases. Knowing that each state may happen multiple times through each lap, it is concluded that the likelihood of the player feeling safe continues to reduce slowly through Lap 2 to 4.

The observed significant increase in caution through each lap reveals that pre-encounter Defence was the most frequently perceived state throughout the experience (M=2.8). It is therefore likely that connections exist between the suggestively threatening audio and the appropriate action response such as

focussed attention and careful movements. This result confirms that a sound which is future orientated with lower intensity is able to prime the player for a pre-encounter defence state.

There was an increase in perceived terror which shows that the participants were more susceptible to startle through each lap. Although the scores were not as high as the other states. A possible explanation for this might be due to the wording of the question. For deducing post-encounter defence, participants were asked how often they were startled or frozen. Compared to other states, being startled or frozen was less likely to happen than feeling safe or cautious.

Another important finding was that the circa-strike defence had the largest total increase (35%) from Lap 1 to 4. The average horror perceived in Lap 4 was 78%. The scenarios built through narrative audio in Lap 1 to 3 proved in making the player feel that they were under immediate pressure towards the end. However, it is important to bear in mind the possible expectation bias in these responses. It is possible that the participant's fear response was more significant in Lap 4 as they were aware that there were only four laps. A possible solution to this is to improve the level design in order to guide the player through each lap without the need to let them know how many laps there are.

Nevertheless, these findings support the concept of a VAEoF for effective audio design. Hence, it could conceivably be hypothesised that the perceived characteristics of a sound decide the cognitive direction of a fearful experience, simultaneously priming the player for appropriate behaviour and emotional response to audio stimuli.

Conclusion

The present study was designed to determine the interactions between audio stimuli and emotional response towards each of the four stages of fear. Based on the VAEoF, it has given insight into applying this theoretical framework to communicate affective game audio design.

The Relief, Caution, Terror and Horror states emerged as reliable predictors when applying the appropriate classification of audio. Based on quantitative and qualitative analysis of the player's experience, the findings support the theory presented by Garner (2013). Implementing the suitable audio classifications for each fear state can be exploited in order to manipulate a player's fear response, consequently, priming the player for appropriate action and responses to sound.

This result shows that the VAEoF has the potential to deliver affective experiences through informed audio design which is able to guide a player's perception of sound. It seems possible that audio designers (especially ones involved with horror) can apply this theory to predict the action and response of a player through sound.

It is unfortunate that this research did not include the collection of physiological data as well as the psychological effects of the player. Therefore this study was unable to obtain and interpret the suggested ANS and SNS responses in the framework. This limitation means that further work is required to establish the physiological effects of the participant through each state of fear. By doing this, it is possible to assess the effectiveness of audio stimuli through biofeedback.

This constraint has given rise to some questions that require more study. Fundamentally, the VAEoF can be used as a framework for a possible real-time emotion-led game sound engine. Though more research is required to determine the efficiency of implementing biofeedback systems into commercially available games. Therefore, a natural progression of this work is to explore the possibility of executing this theory of human-computer interaction in already integrated designs (T. Garner, personal communication, May 4, 2020) such as the eye-tracking software in the Vive Pro Eye (HTC, 2019), rather than using third-party biometric software such as iMotions biosensors (iMotions, 2015) which can prove difficult in integrating with game engines.

Conceptualising game audio as a virtual acoustic ecology has brought together this interdisciplinary research in order to explore the relationship between the player, sound and environment within a fear scenario. Taken together, the result of this study indicates the usefulness of such models as the VAEoF. It proposes the question of whether other types of emotions are possible to develop into a framework of virtual acoustic ecology, such as the competitivity of players in the growing popularity of Electronic Sports research (Pedraza-Ramirez, Musculus, Raab, & Laborde, 2020).

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Appendix A

Further Information on the Acoustic Community

Truax's (2001) idea of an acoustic community links sound, the listener and the environment as an interconnected system of two-way relationships. This approach is viewed through the exchange of information rather than sound propagation as a form of energy transfer, therefore, the meaning we derive from sound and how we interpret this is the backbone of this model. The listener within this model is also a 'soundmaker'. Therefore, the interactions players have with each other and to the game environment determines the game soundscape, but are also a crucial part of its maintenance due to the fact they are a constructive part of the game soundscape.

Appendix B

Further Information on Diegesis

Jørgensen (2011) makes an interesting point on Grimshaw's (2007) taxonomy of game diegesis; that all sounds that provide relevant information for understanding the game world act as diegesis sound. Therefore, even the background music that a players avatar cannot hear continues to act as a signal towards the player. Jørgensen (2007) introduces a model that refers to the divide between diegetic/ nondiegetic by introducing the term transdiegetic sound. This allows both diegetic and nondiegetic sound to address and communicate to each other. The sounds of the user interface is an example of transdiegetic sounds, it is not technically part of the gameworld but still provides valuable information to the player through feedback and warnings (Jørgensen, 2007).

Appendix C

Further Information on Modes of Listening

Listening is a process to gather information about the environment that is around us. It can be seen as the focus and attention we have to our acoustic ecology and therefore affects the way we experience and engage with other players within the game. There has been a significant amount of research of listening modes, and more recently attention has been given to game sound ecology and the listening modes that have risen from this new area of study.

Grimshaw and Schott (2008) augment film theorist Michel Chion (1994) three types of listening for FPS games and suggest that causal and semantic are the more important types of listening for players within a competitive environment; Players listen in order to calculate details such as distance from an enemy (causal listening) and understanding semantic information such as global audio cues (semantic listening). Furthermore, Grimshaw and Schott (2008) propose a fourth mode of listening called navigational listening. This incorporates the use of orientation within a 3-dimensional environment, where players are required to be aware of the localisation and directionality of certain sounds in order to navigate between spaces within the virtual world.

Appendix D

Further Information on Emotion and Interactivity

Players are able to listen and attend to a sound in-game and perceive its meaning but also able to evoke and create sounds themselves, contributing to the thought of viewing virtual worlds as an acoustic ecology. Collins (2013) presents a nonhierarchical spectrum of interactivity between a single player and the game which calls attention to the different forms of interactivity that could happen from cognitive psychological actions.

The category of inter-personal interactions is most valuable to this study as it associates to the theory of acoustic communication through concentrating on the player on player interactions with each other through sound. From this, we can acknowledge the fact that players can not only role-play and listen to sounds through their in-game avatar. But are also able to use their own voice that is outside the game world to communicate and interact with other players within the game world, contributing to the web of sonic interactions within the game's acoustic ecology.

Appendix E

Visual Game Design Details

The title derives from the traditional Welsh folk song sung about the troubles of a harassed housewife, in which the game's plot follows. The player awakens to find themself in a corridor of a dark house, as they explore the level a narrative unfolds from a TV radio station in which the radio presenter reports the killing of a family by their father.

The game was created in Unity 2019.3.7 which used a custom made level from the asset store which was augmented to fit this research. The graphical assets (Chilla's Art, 2019) were inspired by Resident Evil 7: Biohazard (Capcom, 2017). The opening scene in which the character begins follows the same design as Garner's (2013) level. It is described as an 'initial sense of familiarity and security via recognisable architecture and everyday props'. The decision to follow this design was to avoid the over dramatised setting of a 'spooky' Halloween style scene. Therefore the level takes place in a 'seemingly' normal suburban household.

Appendix F

Examples of placing Sound in Context for Fear Manipulation

The radio is an example of this. The presenter reports the murder of a family by their father. The sound design follows this narrative by sonifying the events on the day of the murder, including the arrival of the father in the car, to the mother cleaning in the kitchen, leading to the death of the three family members. By putting these sounds in the context of a situational framework, it is speculated that the sounds may be effective in successfully manipulating fear response.

The sound of the clock is also an example of this. Although, not relaying specific, in-context information like the radio, but allowing the player to attach their own semantics to the sound. The fact that the clock raises in tempo over each lap until it becomes an alarm clock in the final is supposed to prompt a sense of perceived urgency and act as an auditory warning sign (Edworthy, Loxley, & Dennis, 1991). Furthermore, it also acts as a chronoplast, communicating temporal movement in the game. The functions of sound within the virtual resonating space have been described through Grimshaw's (2007) proposed terms in order to define the perception of and immersion within the game world.

Table F1. Key Sounds, Modality, Parameters & Function

Key Sound	Modality	Parameters	Function
Clock	Tempo	Tempo increase	Chronoplast (Temporal movement)
Lights	Pitch	Pitch increase	Choraplast (Defining virtual space)
Radio	Distortion	Distortion increase	Choraplast (Defining virtual space)
Gunshots	Attack	Very short attack time	Aionoplast (Specific temporal paraspace)
Girl scream	Sharpness	7dB gain	Choraplast (Defining virtual space)
Mother Whimper	Reverb	Obscures localisation	Choraplast (Defining virtual space)
Wind	Pitch + Sharpness	Pitch + Volume increase	Topoplast (General paraspace)
House 2D Ambience	/	/	Topoplast (General paraspace)

Appendix G

Preliminary Testing Feedback and Changes

The feedback gathered reflected the need for changes in the GUI (graphical user interface) and overall brightness, as well as to solve problems in visual bugs and optimise builds to increase the performance on PC and Macintosh platforms.

The GUI options on the main menu were either missing or cut halfway from the screen due to differences in resolutions and screen sizes. In order for this to function on different monitors and resolutions, the GUI was moved from the bottom left side and anchored to the centre of the screen for visual ease over an aesthetically pleasing menu screen.

A brightness slider was implemented and can be manipulated to the needs of the participants during the gameplay. Although care was taken to not remove the dark and shadowy design of the game, they are also advised to make sure that their brightness is not set too low on their computer.

The visual bugs may harm the immersion or experience of the participant. Therefore they were resolved by making sure there were no colliding textures on the ceiling or the double doors or anywhere else on the level.

Overall, participants that used PCs had more success than Macintosh users. Unfortunately, participants on Macintosh could not run the game due to major performance issues in which the game froze their computers regardless of being on desktop or laptop. In order to solve the problem of performance, the game must be optimised better for both platforms.

Conducting a preliminary test has aided in ensuring most importantly, that the game is playable. However, it has also provided an insight into how user-friendly the game is to download and roughly how well it will perform on certain platforms before conducting the experiment

Table G1. Preliminary Testing Volunteer Information

Volunteer	CPU	GPU	RAM	Resolution	Feedback
1	Ryzen 7 3700	GTX 1080 TI	16GB	1440p	-Visual bugs on the ceiling and double doors -Thought the loading of level 2 was a glitch
2	Intel Pentium Gold 2.3GHz	Intel HD Graphics 610	4GB	1080p	-Unable to play as no GUI options on the main menu
3	Ryzen 5 2600x	GTX 1050	16GB	1080p	-GUI options were cut from the screen on the main menu but were still able to continue and play -Performance issues with smooth play then sudden long lag spikes -Brightness was too low and impaired orientation in darker places
4	Intel Core i5 2.7 GHz	Intel Iris 6100MB	8GB	Apple Macbook Pro (Early 2015)	-Unable to play due to poor performance graphicly -Although audio quality and performance was fine
5	Intel Core i5 2.7GHz	Intel Iris Pro 1536MB	8GB	iMac (Late 2013)	-Unable to play due to extremely poor performance in both graphics and audio

Appendix H

The Most Significant Emotions Felt

The table below displays the participants response when asked what emotion they felt the most.

Table H1. What was the Most Significant Emotion you Felt Through the Experience?

Participant	Most Significant Emotion Response
1	Analysis, curiosity, fly-on-the-wall
2	The radio created this very unique emotion of being in the same house as the murderer. The audio cues always surprised me as I never knew what was going to happen.
3	Confused
4	Uneasy
5	Unease
6	Anxious
7	Curiosity
8	Anticipation
9	Curiosity. At the experience and experiment itself but also the story the radio was making throughout made me curious and I listened to the entire recordings to make sure I didn't miss anything.
10	Caution
11	Overwhelming at times
12	Unprepared
13	Fear
14	Curious as to what came next
15	Curiosity
16	Freaked out

Appendix I

The Most Memorable & Intense Moments

The table below displays the participants response when asked to describe the most memorable & intense section of the game

Table I1. Please Describe the Most Memorable & Intense Section of the Game

Participant	Most Memorable & Intense Response
1	Walkthrough 3 and ending of 4
2	When I started to feel like I was getting a little less scared, A little child said "mum" in a very scared way with a bang straight away. This sent shivers down my spine and I felt uncomfortable to be in this dark house.
3	One surprised moment but I don't know what lap it was.
4	The audio in the game certainly held up and was utilised really well with timing, location and volume.
5	Where the bloke says 'look behind you'
6	Lap 2 kitchen noises (all kitchen noises, really)
7	When I was in the living room, and the news on the radio started to "malfunction" and some sort of evil voice was audible, and in that point I heard something from the corridor which was scary. I also found the accelerated clock ticking in the 4th round interesting, I felt like I need to find out (or I hope I will find out) why is it ticking faster now than before.
8	Just before the end i thought i heard footsteps and when i looked round the door was open, thought something got out of the kitchen
9	Most memorable was the first time hearing the audio on the radio, but the most intense was the buildup where I knew something was coming at the end but didn't know when/where.
10	The sound of the opening door behind me right at the end, and turning to see it was open.
11	Ticking clock
12	The final bit where the door opened behindme
13	On the 3rd loop (?) when the radio said "Look behind you" even though I was 99% sure it was nothing I didn't want to turn around. (Also also played a majority of it facing the floor because it was scary)
14	The Crunch at the end during the black screen bit.
15	Probably the part where the woman screamed on lap 2 or 3 (its quite loud to be fair)
16	Lap 4

Appendix J

Questionnaire Results

The table below displays the questionnaire results as a whole.

Table J1. Questionnaire Results

Timestamp	Please check the box below after	What gender do you identi	What is your age?	How much experience do	Are you familiar with mou
27/04/2020 15:18:46	Sign Disclaimer	Prefer not to say	18 to 24	10	Yes
27/04/2020 15:19:12	Sign Disclaimer	Male	25 to 39	10	Yes
28/04/2020 13:59:30	Sign Disclaimer	Male	25 to 39	7	Yes
28/04/2020 14:47:55	Sign Disclaimer	Male	25 to 39	7	Yes
28/04/2020 16:39:56	Sign Disclaimer	Male	18 to 24	10	Yes
28/04/2020 17:16:12	Sign Disclaimer	Male	18 to 24	8	Yes
28/04/2020 17:41:05	Sign Disclaimer	Male	18 to 24	9	Yes
28/04/2020 17:44:25	Sign Disclaimer	Male	25 to 39	10	Yes
28/04/2020 17:54:14	Sign Disclaimer	Male	40 to 60	10	Yes
28/04/2020 20:47:52	Sign Disclaimer	Female	25 to 39	7	Yes
29/04/2020 13:04:23	Sign Disclaimer	Prefer not to say	18 to 24	5	Yes
29/04/2020 15:16:48	Sign Disclaimer	Male	40 to 60	3	Yes, but not much experie
29/04/2020 16:52:47	Sign Disclaimer	Male	18 to 24	9	Yes
30/04/2020 00:03:50	Sign Disclaimer	Male	25 to 39	8	Yes, but not much experie
01/05/2020 22:24:33	Sign Disclaimer	Male	25 to 39	5	Yes, but not much experie

What is your FPS (First P	What is your horror game	How often did you feel saf	How often did you feel the	How often did you startle/	How often did you feel un
2	1	3	4	1	2
3	3	3	2	1	1
3	3	1	3	4	3
3	3	4	1	1	1
3	4	4	2	2	1
3	2	3	1	1	2
3	3	4	1	1	1
4	2	4	3	1	1
3	3	4	3	1	1
3	3	1	4	4	4
1	3	4	1	1	1
1	1	4	2	1	1
3	2	2	1	2	2
3	3	3	2	1	2
2	1	2	2	2	2

How often did you feel sa	How often did you feel the	How often did you startle/	How often did you feel un	How often did you feel sa	How often did you feel the
3	4	1	2	4	4
2	2	1	2	1	3
1	4	4	4	4	4
3	2	2	1	2	3
3	3	2	1	4	4
2	4	1	3	3	3
3	3	2	2	2	4
4	3	1	1	2	4
4	1	1	1	2	3
1	2	4	3	1	4
3	1	2	1	4	1
3	3	4	1	2	4
2	3	3	3	1	3
2	3	2	3	1	3
2	2	3	2	2	2

How often did you startle/	How often did you feel un	How often did you feel sa	How often did you feel the	How often did you startle/	How often did you feel un
3	3	4	4	4	4
3	3	1	3	3	4
4	4	4	4	4	4
3	2	2	3	4	4
1	1	4	4	1	1
1	2	2	4	2	3
3	4	1	4	3	4
2	2	2	4	2	3
3	1	3	1	1	1
3	3	1	4	3	3
1	1	3	2	2	2
3	1	1	4	3	4
3	3	1	4	4	4
2	3	2	3	2	3
2	2	2	2	2	2

How immersive was the e	How difficult was the expe	How scary was the experi	How intense was the exp	How emotional was the e	How well did the game pe
4	2	3	4	4	4
3	1	3	2	2	3
4	3	4	4	4	3
3	1	3	2	2	4
3	1	2	2	3	4
4	1	3	3	4	4
3	1	3	3	2	3
3	1	2	2	3	2
1	1	2	1	2	4
4	1	3	4	3	4
1	1	1	2	1	4
4	2	4	4	4	4
2	3	4	4	1	4
3	2	2	3	2	4
2	2	2	2	2	2

What was the most signifi	Please describe the most	If you have any other thoughts or feedback please express this here
Fear	On the 3rd loop (?) when	I'm still shaking
Caution	The sound of the opening	Very unsettling, very good use of ambience to fill gaps between events. The pacing was good, as I didn't
The radio created this ver	When I started to feel like	The world outside could be seen quite easily as I navigated around corners and dead ends. This could ha
Curiosity	When I was in the living r	I expected sounds to start when the game menu comes up, if not music, then some wind rumble and crea The sounds in the game were really good quality and truly enhanced the immersive feel!
Anticipation	Just before the end i thou	I was able to slightly clip through walls which distracted me from the game for a moment
Curious as to what came	The Crunch at the end du	Absolutely sick mate
curiosity	Probably the part where t	Add vsync/gsync so there isn't so much screen tearing and maybe extend wall collisions as you can see
Curiosity. At the experien	Most memorable was the	The game played okay but it was very dark (playing during daytime, but I have bright lights for green scre The audio cues instilled a sense of intrigue and anxiety into the atmosphere. The moment when the radic The sprint instruction was in the back of my mind of needing to use it, but I never did (except for testing it
analysis, curiosity, fly-on-	Walk through 3 and endin	I would have preferred sounds that didn't sound stock and a bit more logic applied to the choice and dyna
freaked out	lap 4	
Overwhelming at times	Ticking clock	
Unprepared	The final bit where the do	I liked the plot and story
Unease	Where the bloke says 'look behind you'	
anxious	lap 2 kitchen noises (all ki	Cool idea, so many different things you could try e.g dog bark as you round a corner
confused	one surprised moment but	I don't know what lap it was.

feel like I was constantly bombarded with things happening, but it was enough		
ave been enhanced by putting the level into a darker setting outside or just blac		
aking wood noise would be nice there, to set the mood of the game. Would hav		
outside the map that way. If this was a demo of a full featured game I think id b		
en setup and had to turn them off to navigate through dining room as it was co		
said "behind you" I did look behind and kept peeking every few seconds just t		
once).		
amics of sounds of mundane objects (television sounded like radio, indoor light		