BEYOND THE NOISE

AN EXPLORATION OF INFORMATIVE SOUND DESIGN IN VIDEO GAMES

BY

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ABSTRACT

Informative sounds in video games are those that are played with a functional purpose. These sounds are meant to inform the player of some change in the state of the game, be it in their character's status or something in the environment around them. This thesis seeks to deepen the understanding of this type of audio through a series of experiments measuring the play experience of a game as affected by different sonic conditions. The results show a need for informative audio feedback, and define the boundaries between abstract and non-abstract game sounds, showing that there is a contextual difference in effectiveness and experience between the two. There were, however, no statistically significant physiological effects relating to the absence or presence of these sounds. From these results, a set of sound design guidelines are contributed, as well as a deeper understanding of game sound and several areas for future research.

KEYWORDS: game audio, game design, game user research, mixed methods

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LISTINGS

ACRONYMS

DotA 2 *Defense of the Ancients 2*

EKG Electrocardiography

EMG Electromyography

FPS First-Person Shooter

GAMERLab Games and Media Entertainment Research Lab

GEQ Game Experience Questionnaire

GSR Galvanic Skin Response

GUR Games User Research

HR Heart Rate

IEQ Immersive Experience Questionnaire

IMI Intrinsic Motivation Inventory

LDW Losses Disguised as Wins

NS NoSound

PANAS Positive and Negative Affect Schedule

PES Play Experience Scale

PENS Player Experience of Need Satisfaction

PX Player Experience

S Sound

SAM Self Assessment Manikin

SDT Self Determination Theory

TIM Tactile Interactive Multimedia

UOIT University of Ontario Institute of Technology

UX User Experience

Part I

INTRODUCTION

1 INTRODUCTION

1.1 OVERVIEW

This thesis discusses game audio from an information technology and design perspective. In this chapter in particular, I describe the gaps in current research that motivated me to conduct the research related to the thesis. Game designers have long understood that designing video games is at its heart about designing interesting decisions for players. Audio can be used as an aid for making decisions in video games. Knowing how to use sound effectively is an essential game design problem, so I focus my thesis on ways in which audio is important for player feedback. To investigate this, I had to a create a game with a logging framework. This formed the technological foundation for my thesis statement, in which I affirm a significant difference between abstract and non-abstract (realistic) informative audio feedback in games. I study this in my thesis within three experimental studies. At the end of this introduction, I outline the contributions of my research.

1.2 MOTIVATION

Game audio has long been an under-represented topic in games research [16]. However, some academic work has been conducted in the fields of spatial 3D sound as well as audio-based games for players with impaired sight [21, 58]. Although work has been done towards defining and classifying different kinds of sounds in games [13, 31], the bulk of the research has been to understand the technical functions of video game audio and how to use game audio for interaction. There is a need, both in research and commercial game development, to understand the ways that game sound and game design inform and augment each other.

To this end, I decided to focus on examining the ways that video game players use sounds within games to make decisions, as well as how those sounds convey information to the players. By obtaining a greater understanding of auditory feedback, both games researchers and commercial game audio designers will see a benefit. New areas for research will be identified, such as the uses of different types of audio for communicating information more quickly and completely to players, and the commercial game industry will be able to put the results of these into practice, creating a better play experience in their games. In this thesis, the notions of abstract and realistic audio are explored within the context of informative game sound. Avenues of future work are identified in the space of sound design patterns and which types of sounds are more effective in which situations. The conclusions reached here, and within future work, will inform sound designers regarding optimal ways to use audio cues to represent player character health.

Furthermore, it is possible that some of my research may be applicable outside of games as well. Sounds are used in everyday life to convey information to people. Most of the time, these are high-pitched, alarming sounds, for example, those made by alarm clocks or smoke detectors. However, information which has been encoded within sounds is also prevalent in many professional environments, including those in the medical sector (e.g. heart-rate monitors) and public safety (e.g. police sirens, fire alarms). It is possible that by gaining a better understanding of the way we interpret and react to audio information in games, there may be a portion of those findings which can improve the design of these kinds of sounds in the real world. As a concrete example, I am interested in investigating whether an abstract sound is more likely to evoke a player response than a more realistic or life-like sound in a game. In the following, my thesis statement outlines and defines this distinction.

1.3 THESIS STATEMENT

There is an important distinction between abstract and realistic audio information feedback in games. Video game sound design can be informed and improved by understanding this distinction and the effects of abstract and realistic audio information on player experience.

I will go further into relevant definitions in Chapter 4. For now, we can understand abstract audio information as sounds which are synthetic and do not occur in a natural environment, so they are not produced by humans interacting with their environment. These sounds are not inherently representative of an object in the environment, they are sounds that seem out of the ordinary (they could be considered non-diegetic by another definition). In comparison, realistic sounds have an identifiable source and are usually produced by the interaction of humans with their environments (many of them could be considered diegetic by another definition).

This thesis presents a series of exploratory experimental studies into auditory information feedback in video games, and an understanding of how to more effectively use this to make decisions about what action to apply (e.g., typical game actions like attacking or taking cover to protect oneself). The aim of the work is to further the field of games research in a manner that is also applicable to commercial game design, through increasing our knowledge of different types of sound information.

1.4 RESEARCH CHALLENGES

The challenge of conducting research into video game audio is that off-the-shelf game titles do not necessarily allow researchers to tamper with the source code of the game to substitute audio files. Sometimes sound is even generated procedurally during gameplay. So, for my research, I decided to build a game prototype which was enjoyable to play, but could also be used as a research tool to collect interaction data. Furthermore, the methods that I chose to evaluate the player experience needed to be able to give a broad assessment of the effects of audio information on players, but they had to be specific enough to draw meaningful conclusions. Therefore, I experimented with several different measures in the experiments, but gathered the most valuable insights from my qualitative interviews with players.

1.4.1 *Relevance*

I wanted to ensure that the research conducted for this thesis was valid and that my results were generalizable in the academic community as well as in the game design community. Therefore, I created a fully playable 3D video game that allows to track anything related to the playing of sound in the game environment. This gave me the necessary flexibility to create the games around my research questions, because most commercial games do not provide audio options that are robust enough for the purposes of this thesis; it was necessary to develop a game/tool hybrid to fulfill the requirements of both research and entertainment.

1.4.2 *Game Design*

In consideration of ecological validity, a game was developed together with a small team of undergraduate programming assistants. It was necessary to build a game that was both fun to play and had a suite of logging processes built into it. We recorded the player's movement throughout the game world, and logged game events of interest. Specifically, we tracked the collection of objectives, as well as any time some action caused the player character's health to change. For a detailed overview of the game and its logging processes, see Section 3.3. The decision to build the game in-house came naturally, as its purpose as a research tool is to give participants an experience as close as possible to that of a game they might play in their own home.

1.4.3 *Evaluation*

Finally, it was necessary to choose the right evaluation methods out of the multitude available. Similar to the concerns expressed while discussing relevance, I sought to choose the methods that would provide me not only with a wealth of information, but enough to draw specific conclusions from each experiment. The first study gathered a large amount of data, including game metrics, questionnaires, and physiological measures. This allowed me to see any specific changes in the play experience, including not only self-reported measures and game performance, but also any underlying physical effects. This added some time to the overall length of each experimental session, but it was deemed acceptable based on the breadth of data gathered. In further studies, physiological measures were foregone, as Study 1 did not yield any significant physical effects.

1.5 CONTRIBUTIONS

This thesis provides the following contributions to the field of Computer Science and specifically within the application areas of Human-Computer Interaction and Games User Research:

- *A greater understanding of the role and use of audio information in video games*: The taxonomy of abstract and realistic audio feedback was explored in studies 2 and 3. From the interviews in study 2, an initial assessment of what contributes to the abstraction of game sounds was made, and both external and internal factors in determining the level of abstraction are proposed in this thesis. In study 3, it was found that realistic sounds may be better suited to indicating player-centric events in First-Person Shooter (FPS) games.

- *Sound design guidelines for informative game audio*: Based on the results of the experiments performed within this thesis, some guidelines have been created to assist video game audio designers in creating more effective informative audio feedback. These will offer insight into the usefulness of both abstract and realistic sounds for informative feedback, and outline a few contextual cases where one type of audio is more useful than the other for giving information to the player.

- *The game framework*: A Unity game was developed to test the effectiveness of different game sounds. It provides a way to easily change which audio is being played for an event, and offers a logging system to record important data about the player character's statistics and movement. More work is still needed to make the system extensible, as well as branching it to other genres of games.

1.6 ORGANIZATION

In this chapter, I have discussed the motivations for my work, as well as outlined the concerns that must be addressed when designing studies to explore my research goals. I have also presented the main focus of the work within this thesis, and described the contributions that my research has made to the field of video game audio. In the remaining chapters, I will cover:

- Chapter 2: A brief overview of the current status of game audio research, as well as a description of the approaches used in Games User Research (GUR) and how it has contributed to games and game design.

- Chapter 3: An initial exploratory study into how informative game audio affects the player experience in an FPS game. It explores the question of how the absence or presence of audio, related to changes in the player character's health, affects the play experience of an FPS game. This chapter contributes the first set of sound design guidelines. It also identifies the issues examined in the remainder of the work in the areas of abstract and realistic audio feedback.

- Chapter 4: A brief follow-up to the study detailed in Chapter 3, in which game designers are interviewed about how they would classify different types of game sounds. The aim of this study is to develop a usable definition for abstract and realistic audio in games. The interviews contribute a stronger sense of what constitutes both of these, informing the choices of feedback audio studied in the third experiment.
- Chapter 5: A study exploring the differences in player preference and performance when completing game-based tasks using abstract and realistic audio cues. Specifically, the player actions of environmental awareness and health perception were studied. This final chapter contributes the remainder of the sound design guidelines, as well as details areas for future research within the scope of informative game audio.
- Chapter 6: The results of the studies are discussed, along with a conclusion to the thesis. Additionally, the limitations of the work are presented, and future areas of research are suggested.

2 RELATED WORK

2.1 OVERVIEW

In this chapter, I examine the fundamental literature in understanding and positioning the work performed in this thesis. First, I address the field of game audio, including current research trends, as well as many practices and models that are currently used. To understand the ways that game audio is used to provide different kinds of information to players, I will discuss music and audio games, different classifications of game sounds, as well as specific principles in designing audio feedback. Secondly, I discuss the field of Games User Research (GUR), including its goals and popular methodologies. As GUR is a relatively young field, its techniques are constantly evolving. To this end, I will describe both traditionally used techniques like popular questionnaires and self reporting methods, as well as more advanced techniques like psychophysiological and mixed methods. To understand the human factors of informative game audio, it is important to be aware of the benefits and drawbacks of each of these methodologies, and the ways that they can augment one another to give a more complete picture of Player Experience (PX). These methods will provide a set of tools to use in the studies outlined in chapters 3 to 5 and allow for the analysis of the effects of informative game audio on video game players.

2.2 AUDIO IN GAMES

Game designers and developers are constantly researching new techniques and design patterns to improve their products. Unfortunately, the area of video game audio has been relatively under-explored compared to other game elements such as visual aesthetics [20]. This may be due to pre-existing sound design principles outside of the context of games, or simple that visual aesthetics are more immediately visible and appealing. This mirrors the idea that game audio has not driven the market to nearly the same extent as graphics. However, the integration of audio into gameplay has advanced the diversity of games and even paved the way for new games being driven by more enhanced aural stimulation [16].

Some of the first creative explorations of audio in commercial games occurred when game designers attempted to integrate the game audio, as well as interactions with it, into the core mechanics of their games. One of the first successful games to do this was *Parappa The Rapper* (Sony Computer Entertainment, 1997), on the Sony Playstation. The game featured a 'call and answer' mechanic where a character on screen would perform a line of a song, and the player would be required to mimic their line afterward by pressing specific buttons on their controller to the rhythm of the background music [67]. As basic as this interaction was, it paved the way for modern music games such as *Dance Dance Revolution* (Konami, 1998), *Guitar Hero* (Harmonix, 2005), and so on. These music video games have been defined by Williams as "audiovisual games in which the player is actively involved in the creation or playback of music of rhythm." [67] He also warns that these games are not to be confused with audio games, which were originally developed as games specifically for people with visual impairments. Audio games therefore lend themselves well to the discussion of informative game audio and will be discussed at length below.

2.2.1 *Accessibility and Audio Games*

Audio games, in contrast to music games, are game that have complete auditory interfaces and do not require the use of graphics in order to be played [21]. They have made gaming more accessible to players with limited or no vision [16]. In order to assist in the development of these games, the Tactile Interactive Multimedia (TIM) project was developed. The TIM project is a piece of software that works together with a tactile and keyboard, made modular by inserting different pieces of paper embossed with objects and words written in Braille. Through the use of this software, it was not only possible to develop games for children with visual impairments, but also those that had not yet developed the ability to read [3]. Many design considerations were developed for TIM games, many of which are relevant for designing audio in games outside of the audio games umbrella. Archambault et al. [4] identified the following needs:

- Use proper and higher fidelity audio representations of things. This is necessary as those without sight cannot rely on visual information to provide additional clues to the source of the sound.
- Use tactile input modalities such as overlays or Braille displays. Again, this is due to the inability to have supplemental visual information about the device.
- Integrate enlarged graphical views in order to accommodate those users which still retain some level of sight and can benefit from a visual aid.
- Redesign specific game mechanics or elements, as instructions such as clicking on an item may not be relevant to the input method.
- Provide the player with immediate feedback, in order to increase gameplay efficiency.

Although these elements are quite obviously beneficial for the design of games for children with visual impairments, their underlying principles also make sense in a traditional game design context.

It is important to note that from a design perspective, audio games are still in their infancy and are mechanically simple. *Finger Dance* is a game in which players must press a key based upon the pitch and balance of a drum roll in a piece of music. Although it is entirely playable sightless, players could only provide shallow insights in a usability test, such as having difficulty navigating menus or the challenge level of the game being too easy [44]. Likewise, *AudioBattleship* offered a sightless alternative to the traditional game of *Battleship*(Milton Bradley, 1967), using a tablet interface and spatial audio cues to help users locate their targets. Similar to Archambault et al., Sànchez, Baloian et al. also discovered issues relating to the quality and synchronicity of their audio [60]. Research on audio games is ongoing, but until greater advancements are made in their design, we can only learn a limited range of information about informative audio from their design and implementation.

2.2.2 *Auditory Feedback and Informative Audio*

Informative audio design is essential to producing better games, as there are great limitations when trying to display all relevant information visually [53]. To communicate the information required to make decisions in video games, developers use sound in addition to visual cues. Abstract data is encoded into an auditory form for this; a technique commonly known as *sonification*.

This paradigm is not without its issues, however, and this information must be encoded in a precise way to avoid misinterpretation. One of the largest factors that contributes to the possibility of misunderstanding is simply that the perception of a given user is influenced by their own level of knowledge and experience [25]. Welch and Warren [66] also agree that a person pays attention to differing feedback depending on factors like previous learning. Goldstein [25] elaborates, finding that we actively perceive different things by paying attention to stimuli that we find interesting, making our attention an important part of the way we process information as it directs us to those stimuli which we want to perceive. To that end, we may find that while some users are invested in sound, others could choose to completely ignore it [53]. Fortunately, games are designed in such a way that this is mitigated; in general, games do a good job of teaching their players what certain sounds mean, and which ones require priority to react to.

Using multiple senses (in the case of video games, vision and hearing) to provide information at once can be done in a number of different ways:

- *Complementary*, wherein each sense is provided with useful, but different information to each sense.
- *Conflicting*, wherein the user receives contradictory information across senses.
- *Redundant*, wherein each sense is provided with the same information.

Clearly, when receiving conflicting information, users will generally perform worse, however complementary displays should allow for the user to perform better [40, 55]. Despite the connotations, all three of these approaches could be useful, depending on a game designer's goals.

Ng and Nesbitt [53] detail three different types of approaches to encoding information within sound: auditory icons, earcons, and speech. I will discuss each at length and explain their use within the context of informative game audio.

2.2.2.1 *Auditory Icons*

An *auditory icon* is a pattern based upon an instance of a real world sound, which is intended to provide information about an object or event [24]. For example, when knocking on an object, the noise that it makes can provide us with an idea of what the object is made out of, whether it is solid or hollow, as well as how forceful the knock was. The things that we can infer from auditory icons such as this depend on how well we have learned to interpret the nuances in the sound, in accordance with Goldstein [25] and Welch and Warren [66]. However, due to repeated exposure to different sounds in our environment, we can generally recognize most properties of objects, at least within the real world. Therefore, auditory icons can take much information and encode them into a recognizable form for most people [8]. In games and other auditory interfaces, they can help us get an idea as to what is generating a sound, and even if the source of the sound is important enough to pay further attention to. From there, we can decide if the information it provides us requires that we take some sort of action [33]. For example, when playing an action oriented role-playing game, a player may hear heavy, stomping footsteps. This could indicate to that player that a large or otherwise threatening enemy is nearby, prompting them to make a decision on whether to confront said enemy, or retreat to safety.

By mapping actions, objects, and events to their equivalent real world sound, it becomes possible to provide players with many different kinds of environmental information, such as:

- *Physical events*: If the player throws an object and out of their field of view, the sound that it makes can tell them if their object shattered, bounced, or reacted in some other way to the impact.
- *Invisible structures*: In some games, like in the *Legend of Zelda*(Nintendo, 1986) series, the player can tap on walls using their weapon, and determine if the wall is breakable or not depending on the sound it makes.
- *Dynamic changes*: If a container is being filled with some kind of liquid, the sound it makes will change as it becomes full.
- *Abnormal structures*: When an object is malfunctioning, it tends to make an abnormal sound, indicating that something is wrong.
- *Events in space*: The sound of a door opening or gunfire around a corner can indicate to a player that they are in a possibly dangerous situation. [47]

All of these afford auditory icons to be a powerful tool for game designers and players alike, allowing for the planning of intricate level design that rewards a player for paying close attention to the changes in sound around their character.

Additionally, there are different methods of using auditory icons. In FPS games specifically, sounds can either be pre-emptive, reactionary, or related to feedback. The role of pre-emptive sounds are to tell the player where objects and enemies are before they have the opportunity to attack. Similarly, reactionary sounds help to provide the location of enemies once the player has been attacked. Finally, feedback sounds alert the player to any changes in their important resources, such as health, or ammunition [28]. All of these connections and interpretations can be made due to the way that we understand these sounds in the real world [53].

2.2.2.2 *Earcons*

Earcons, in contrast to auditory icons, don't have any sort of pre-existing context that we can interpret and instead rely on the listener's ability to recognize different variations in music. They work by using some abstract mapping between a musical sound and a piece of data in order to convey something more complex [41]. Earcons are created from different building blocks, called *motives*, which come from musical properties such as rhythm, timbre, pitch, register and dynamics. One drawback to using them is that although we can convey complex and informative sound patterns, they require some amount of overhead in terms of learning what each different motive means. There is also a large caveat in that a certain degree of musical listening skill is required of both the player and designer [53].

Brewster [11] examined the use of hierarchical earcons in order to provide spatial and navigational cues within a tree structure. It was found that although using different layers of motives made it possible to encode more location information within an earcon, there were a finite number of layers (around 4, depending on which specific motives are altered) that could be added before the sound become too confusing and the information was lost entirely. Although not specifically related to games, the work shows that we can encode a surprisingly great deal of information within a single earcon and still be able to interpret it correctly.

It should be noted that some degree of training may be required to understand more complex, layered earcons [11]. However, simplistic earcons are often suitable for warning signals, when designed to be abrupt and shrill. A good example of this is the 'pinging' mechanic in *Defense of the Ancients 2* (DotA 2)(Valve Corporation, 2013), where a player can indicate a spot on the game world to alert their allies of possible danger. This area is then visually highlighted on the maps of the allies, accompanied by a shrill beeping noise that can easily grab the attention of the players. These 'pings' are a mix of a notification noise as well as a warning signal, and player can choose to react to them or ignore them entirely [31].

Earcons can also consist of changes in the game soundtrack. For example, a background music theme changing from a peaceful, melodic tune to a more fast paced one could indicate to players that they have entered a potentially dangerous area. It is worth noting that the music itself is not an earcon; Ng and Nesbitt [53] describe the effects applied to the music as such. Due to their multitude of uses and implementations, earcons allow game developers to convey both simplistic and complex information through variations in sound patterns, although as mentioned previously, must be used and designed carefully as they require some overhead to learn their meaning [53].

2.2.2.3 *Speech*

Speech audio in games is simply any use of spoken language; the most prominent form of auditory communication in general [22]. When appropriate to use, speech audio may be more effective than using earcons in complex situations. One of the factors to consider when examining this is if the meaning of the earcon has not yet been learned by the player, and therefore would require more cognitive effort to decode than listening to speech [19]. By using speech, developers are able to communicate with players that speak the same language in a clear manner. Unfortunately, this is not always the best option, as most game events are time sensitive in some way [53].

Each of these three types of sonification can be extremely powerful tools for communicating valuable, or even critical information to players. By understanding how to make the best use of each, it is possible for game designers to drastically increase the effectiveness of their feedback mechanisms and conveyance of information through audio.

Other applications also make use of informative audio, and have helped to further our understanding of useful ways to implement it. Spatial audio cues can also be incredibly helpful for users to locate things within a virtual environment. Baldis [5] investigated the effects of spatial audio on memory and comprehension during a virtual conference. It was found that when a user was provided with spatial audio, they were better able to identify which conference participant was speaking as well as understand the speech itself as the separation in sound sources increased. They also preferred spatial audio, claiming that it allowed them to pay more attention to the content rather than who was speaking. Additionally, Mereu and Wazman [43] found that spatial audio cues improves performance in locating a point in 3D space on an abstract object. So much so in fact, that visually impaired users were able to locate the target points with the same accuracy as fully sighted users, and going on to outperform those sighted users in an audio-only environment. Furthermore, Collins and Kapralos found that the utility of three dimensional spatialized sound extended to video games as well. They found that it was easy to convey spatial information through the use of spatialized sounds, and that even two dimensional games can be better visualized when they include three dimensional sound [14].

2.2.3 *Game Audio Design*

Despite the field's relative infancy, there have been several authors that are passionate about game audio and game audio research. Collins [13] has positioned her work as a foundation for further research into the area, and laid the groundwork for exploration into the participatory nature of gaming and game audio, both practically and theoretically. She has defined some basic types of game audio that are not found in other mediums, which are as follows:

- *Adaptive Audio*: Any audio that reacts to, or even anticipates gameplay is considered to be adaptive audio.
- *Interactive Audio*: Sound events that occur in reaction to gameplay, such as the swinging of a weapon, are elements of interactive audio. Interactive audio uses auditory icons and sound symbols to help a player identify goals and focus on certain objects.
- *Dynamic Audio*: Any audio that reacts to either changes in the gameplay environment, or in response to the player is dynamic. Likewise, sounds that do not react in such a fashion are categorized as *non-dynamic*. Both adaptive and interactive audio can also be dynamic.

She goes on to further break down the categories of dynamic sounds into examples of both *diegetic* (i.e., the source of the sound exists within the game world) and *non-diegetic* subcategories, fleshing out a rough taxonomy for adaptive and interactive sounds within games [13].

Chion [12] earlier distinguished sounds at different narrative levels for films, wherein diegetic sounds related to synch dialogue and non-diegetic sounds related to conventional background music. Diegesis has also been explored within game sound, and a third distinction, transdiegesis, has been described as interactions between the player and the characters [32].

Furthermore, through the research into spatial sound described above, some implications for audio interface designers have been suggested, such as using audio to allow for a greater sense of spatial awareness of the player. Additionally, remaining consistent with the sound design of a game and focusing on the player's character rather than ancillary sounds seems to be the most effective [14].

Design patterns in general are described as the core of a solution to a recurring problem in a given environment. They consist of three main parts: the *vocabulary*, which is a collection of named or described solutions to a given problem within the field, the *syntax*, which is a description of how and where the solution fits within the design, and the *grammar*, or how the proposed solution actually solves the problem or otherwise provides some benefit. Design patterns by nature are constantly evolving as professionals and researchers continue to develop new and better ways to solve problems. As such, many patterns receive additions, clarifications, or are even challenged outright [1]. Unfortunately, when it comes to sound design, the body of knowledge is held rather informally and is not well-distributed among communities of game developers. Barrass [6] has suggested that sound and sonification patterns should be developed in order to help share this knowledge, and some tools have been developed to specifically assist with this, and help with designing sounds for games in general [2].

Ng and Nesbitt [53] identified these sound design patterns in FPS games:

- *Impending Death*: Usually, when a player's health is low, feedback is provided visually in the form of bloody graphics overlaid on the game screen, or blurred vision. This can lead to a frustrating experience for the player as having their vision obscured in some way while close to death could possibly make mistakes more likely. By reducing the severity of the visual effects and using sound to supplement and add to the severity of the situation, we can provide the same information and low-health panic in the player without adding an unnecessary or unfair element of challenge through drastically reducing what they can see.

- *Local/Global Notifications*: Players are often visually notified about changes in their environment. However, they may not always notice these notifications depending on how many other tasks with the game they are preoccupied with. Using earcons or speech based alarms to augment this notification can make it easier for players to track environmental changes. For example, in *Unreal Tournament* (Epic Games, 1999), when playing a Capture the Flag match, a speech cue informs a team when an enemy takes possession of their flag.

- *Progressive Feedback*: As players complete objectives within the game, new tasks are added, usually showing up briefly on the screen. Since not every player pays attention to what is written on screen, accompanying them with speech audio and/or earcons can be used to draw attention to the important information and reinforce the player's understanding of the cue.

- *Damage*: Typically when a player's character receives damage, the colour of the screen changes and other visual effects may be applied. Like with impending death, the overuse of visual elements can cause some confusion to the player, or cause them to become panicked without a clear understanding of how much health they have lost. Adding some audio to this feedback can make things easier to understand, especially if the audio cues used increase in severity as the player's health becomes lower.

- *Environmental Awareness*: A player needs to constantly be aware of their surroundings in the middle of a game. By using auditory icons to subtly indicate enemy movements, attentive players can more easily identify and track threats in the environment, allowing them greater insight to the challenges awaiting them and giving them an opportunity to plan. Earcons can also contribute to environmental awareness, such as playing a tone when an enemy becomes aware of the player's position, as in *Metal Gear Solid* (Konami, 1998).

- *Impairment*: When a player is struck with a heavy-damage or otherwise disabling items such as flashbangs, their vision is obscured to simulate the disorientation that the character would be feeling. The use of high pitched earcons compounds this effect, and also allows players to differentiate between different kinds of projectiles through the use of familiar sounds.
- *Time Limits*: Many levels or objectives that players must complete are time sensitive in some way. If a timer is shown to the player, it is not usually positioned in a prominent place on the screen, and players are often too busy with more important game tasks to constantly monitor it. Through the use of earcons or auditory icons, it becomes easy to tell a player that they are running out of time, or that a certain amount of time needs to elapse before they can perform an action.

Although it is not yet fully understood, the presence of sound in a video game has been shown to increase the experiences of a player. Nacke et al. [52] performed a study in which participants played an FPS with both music and sound on or off. It was found that players had a significantly better experience playing the game with the sound on.

As helpful as sound can be towards enriching a player's positive experience with a game, there are also findings which warn that sound design can be performed in such a way to trick players. In a study of non-problem gamblers, the effects of sound were examined in relation to Losses Disguised as Wins (LDW)s. An LDW occurs when a slot machine player wins money on a spin, but wins less money than the total amount that they wagered on the spin. It was found that, when a LDWs were accompanied by the same jingle that played when a player experienced a regular win, players would tend to overestimate the amount of spins that they won money on [18]. This raises concern that it is possible to misappropriate effective sound design in games to promote unhealthy addictive player behaviors.

Fortunately, game design has received far more positive benefits from game audio research than negative. For example, Garner [23] has produced an entire thesis on an exploration of fear responses and gameplay using adaptive audio. He explains part of the relationship between a player's fear and the game audio, as well as explores using psychophysiology and biometric feedback systems (discussed later in this chapter) in video game play.

2.3 GAMES USER RESEARCH

GUR is a branch of games research that focuses on the interactions between the players and the game. By gaining some insight into the thoughts and feelings of players during gameplay, it becomes possible to use that information to improve the design of not only the game being played, but also games as a whole. While traditional software testing is more concerned with finding bugs and improving the quality of the software itself, GUR seeks to gain information about the User Experience (UX) through a variety of user tests in order to improve the actual design of a game [46].

GUR is already a fairly well established field, with many researchers in both academia and the games industry pursuing its benefits. It has become popular, and there is a large body of work that has been completed already [7, 49]. The drive to discover more information about the UX and player feelings comes from the idea that these emotions that players experience motivate the cognitive decisions that they are making as they play games [50, 48]. Although many factors are analyzed, the three most researched areas within game user experience are: immersion, presence, and flow [52].

Immersion describes the degree to which a player is involved in a video game. There have been a number of different levels as well as barriers to immersion that have been identified. Things that can detract from a player's level of immersion are mostly contextual, and consist of things such as the player's game preference and the presence of distractions within their environment. The three levels of immersion are as follows:

- *Engagement*: In the first level of immersion, a player needs to overcome any issues they have dealing with their preference of the game. To become engaged, they must invest time, effort and attention to learn how to play the game and familiarize themselves with the way that the controls work.

- *Engrossment*: When a player becomes engrossed, they overcome the barrier of the game's construction. The player becomes emotionally affected by the features of the game and begins to enter a Zen-like state where they are able to play without consciously thinking about the controls.
- *Total immersion*: Finally, a player is considered totally immersed when a player begins to feel cut off from reality, to the point where the game is all that matters.

Total immersion is rare and tends to be a momentary experience, whereas engagement and engrossment are much more common and longer lasting [30].

Presence deals with the degree to which a player feels a sense of spatial presence within some environment [35]. Contrary to immersion, which deals with how involved a player becomes, presence deals with whether they feel that they are actually within the game world. To this end, presence is assumed to be felt much more strongly in virtual reality environments, as they afford more natural methods of interaction and allow for better spatial mapping than traditional displays such as televisions or monitors [65]. Wirth et al. [68] have suggested that there are two prerequisites for experiencing presence: the allocation of the user's attention, as well as their ability to establish a mental model of the environment in question.

Flow is a state that occurs when the skill level of a person matches the challenges that they receive from a situation. While in the flow state, a person may feel as if time is slowing down and that their attention is entirely focused on meeting the challenge they are facing. When this balance between skill and challenge is met, it allows for learning to occur; that is, the person experiencing flow has the opportunity to increase their level of skill by overcoming suitable challenges. On the other hand, if the challenges were too simple, the person could perceive a task as too easy and become bored. Likewise, if the challenge is too high, it may cause anxiety and in the worst case, the person could end up giving up [15]. When in the flow state, a person may notice a change in the way they experience the passage of time, perceiving it to slow down, as afforded by the flow state. It naturally follows that researchers seek to understand flow in games. Nacke and Lindley [50] have used game levels specifically designed for encouraging flow in order to gain more insight on the gameplay experience, and found that different levels evoke different emotional patterns among players.

2.3.1 *Traditional Methods in Games User Research*

There are a great number of techniques that are regularly utilized within GUR. Although each functions reasonably well on its own, many researchers combine methods in order to compensate for some of their shortcomings and get a more complete picture of the data.

Observation is a fairly common method of conducting player research. This is due to its ease of implementation, combined with the potential for providing a large amount of useful data. Behavioural observation simply involves watching a player interact with a game, and trying to make sense of their facial expressions and body language as they play. Generally, the play session is recorded on video and reviewed later, so that no potentially important events are missed. Observing the way players play games and react to situations within them provides a foundation for analyzing both the fun and usability of a game [45].

Think-aloud is a protocol that involves the player describing their actions and motivations as they play a game, in real time. This allows researchers some insight into a player's immediate thought process, and can yield some details that cannot be ascertained through observation alone. Unfortunately, think-aloud does not always come naturally to players, and they may need to be trained to keep their thoughts vocalized during intense or time sensitive moments of gameplay. For this reason, it has been argued by some that this disturbance and its subsequent impact on gameplay causes this method to become ineffective [45].

Heuristic Evaluation is a much more formalized method of evaluation. By choosing one of many existing sets of gameplay heuristics to evaluate against, a game can easily be compared to an existing set of rules and standards. This method has rather low costs to implement, but can easily encounter problems with subjective interpretation of the experts doing the evaluation [45].

Interviews are also commonly used to help evaluate the player experience. By asking a semi-structured set of questions to a participant, researchers are able to gain more information about specific experiences that are reported. Unfortunately, interviews can only generate data regarding the questions that are asked, so it is possible that some information may be missed. Similarly, participants may have trouble recalling certain feelings that they experienced during gameplay and be unable to provide a complete answer to questions. This can be mitigated somewhat by recording the play session and using it to prompt participants by showing them certain events, but this compounds the amount of time required to perform the interview, making it less practical for long sessions or large numbers of participants. [45].

Questionnaires, like interviews, are frequently used in GUR. They are not only convenient, but can also be generalized and provide rapid turnaround in terms of statistical analysis. Asking a player to fill out a survey before or after gameplay is a simple way to get a sizable amount of data from large groups of participants. They do, however, share many of the same shortcomings as interviews; data can only be gathered on the questions that are asked in the questionnaire, and it is not possible to follow up with participants on potential areas of interest. The ideal time to administer different surveys has also been called into question by some, attempting to balance uninterrupted gameplay with the quality of a participant's responses [45].

2.3.1.1 *Common Questionnaires*

The following is a list of several standardized questionnaires that are commonly used in GUR experiments:

- *Game Experience Questionnaire (GEQ)*: The GEQ is a questionnaire that seeks to measure three different areas of the gameplay experience. It focuses on the core experiences during gameplay, the social aspect of gaming with other players, and the experiences that a player has once they have stopped gaming. Although it is difficult to use in cases where participants have only a short time to play the game, it provides for a broad look at many aspects of the game experience, including positive affect, immersion, competence, challenge, and flow [29].

- *Immersive Experience Questionnaire (IEQ)*: The IEQ is used to measure immersion in games. It was originally developed through experiments seeking to determine if it was possible to measure immersion subjectively. There are 33 total questions, 32 of which are paired as positively and negatively worded versions of the same question, so as to account for possible wording effects. A respondent is asked to respond whether they agree with each of these statements on a 5 point Likert scale. The final question simply asks the respondent to rate how immersed they felt overall on a scale from 1 to 10. The final immersion score is calculated by totaling the responded values for each statement, adding for positively worded phrasing and subtracted for negatively worded phrasing [30].

- *Intrinsic Motivation Inventory (IMI)*: The IMI measures a participant's subjective experience to a given task or activity in an experiment. It consists of several subscales, including interest/enjoyment, perceived competence, effort, and pressure/tension experienced while performing the task. Each subscale has a different number of items, and all are answered using a 5 point Likert scale. There is one item in each subscale that is considered "negative" and must be re-coded by subtracting the reported value from 6 before the final scores are calculated. To calculate the score for a given subscale, the average of all responses relating to that subscale are averaged, for an overall score between 1 and 5. There are several versions of the IMI, but the one used most often consists of 18 items [39].

- *Positive and Negative Affect Schedule (PANAS)*: The PANAS was first developed to be a reliable and valid alternative to other inadequate mood scales. Upon testing, it was found to be internally consistent and stable at appropriate levels over long time periods. The PANAS consists of two mood scales, each with 10 items. One scale measures positive affect of the respondent, and the other measures negative affect. Each scale consists of adjectives relating to either positive or negative affect, and respondents are instructed to indicate to what extent they feel that way on a 5 point Likert scale. To score the questionnaire, each item of each scale is added together, resulting in a score between 0 and 50 for both positive and negative affect. Although respondents can be instructed to fill in the survey considering any time period, GUR often focuses on momentary measures, asking participants to simply recall how the feel over a past play session. The typical average momentary values are 29.7 for positive affect, and 14.8 for negative affect [64].

- *Player Experience of Need Satisfaction (PENS)*: The PENS connects the concepts from Self Determination Theory (SDT) [17] to the field of gaming. SDT states that there are 3 basic needs that must be met in order to foster psychological well-being and intrinsic motivation: competence, autonomy, and relatedness. In addition to these three scales, the PENS also adds presence and intuitiveness of controls, for a total of 5 subscales. The additional subscales were added as they are constructs that are specific for interacting with game environments. Each subscale asks participants to reflect upon their play experience and rate their level of agreement with a number of statements. The questionnaire is usually scored on either a 5 or 7 point Likert scale, and 2 subscales have elements that need to be re-coded. The final scores for each subscale are calculated by averaging each item within them [59].

- *Play Experience Scale (PES)*: The PES was developed through literature review and empirical studies in order to measure a participant's play experience in video games. Unlike some of the other questionnaires that have been adapted for use with games, the PES was made specifically with games in mind. IT is divided into the subscales of autotelic experience, freedom, focus, absence of extrinsic motivation, and a direct play assessment. Until the development of this questionnaire, there was not a standard scale for assessing play experience subjectively. Although a 16 item version of the PES has been shown to be reliable in terms of this, the authors recommend further validation modification before it is useful outside the scope of video games. The subscales are scored on a 6 point Likert scale, with some questions requiring re-coding as in the IMI [56].
- *Self Assessment Manikin (SAM)*: The SAM is a questionnaire that measures the levels of pleasure, arousal and dominance associated with some stimulus. It differs from other questionnaires in that it is pictoral, and asks a respondent to indicate which picture best describes how they currently feel, rather than using specific statements. It is widely used in experimental psychology and offers a quick way of tracking a participant's response to the experimental condition [9].

2.3.2 *Psychophysiological and Mixed Methods*

As the field of GUR has grown, so have the methods used in its experiments. As the need to understand the finer points of the play experience grow, we turn to techniques beyond observation and self reporting. Physiological measures offer some insight into the physical state of a player during gameplay, and can be a powerful tool for analysis [51, 45, 38]. Some of the more popular physiological measures include:

- *Galvanic Skin Response (GSR)* refers to the conductivity level of the skin. It is associated with the level of physical arousal of the participant [37]. Therefore, it can provide some insight into a player's level of attention or excitement during gameplay. GSR is measured using electrodes that measure the change in conductivity over time, usually attached to the fingers. Although the reliability of GSR has recently been called into question, Ogorevc et al. [54] have shown that the resolution of the measurement instrument does not contribute to any measurement uncertainty.

- *Facial Electromyography (EMG)* is the measurement of electrical activation across certain muscles of the face. Like GSR, it is measured using electrodes, attached to a chosen muscle on the face. Usually this is the corrugator supercilii (above the eyebrow) or zygomaticus major (on the cheek). Researchers have shown this to be a reliable indicator pleasant or unpleasant emotions felt by a participant [10]. Interestingly, there has also been an effort to automate facial expression recognition for the purpose of evaluating players. Although more work is needed, it is possible that it may provide enough information to infer some details regarding the player experience [61]. The use of GSR and EMG together is quite common, as GSR only provides the level of arousal of the participant, while the results of EMG provide some valence, indicating whether the experience is a positive or negative one.

- *Heart Rate (HR)* and other associated cardiovascular measures can be obtained through the use of Electrocardiography (EKG). Using HR, it is possible to gain some information about the emotional activity of a player, as it has been used in conjunction with temperature to differentiate between positive and negative emotions. Additionally, by studying the variability, the amount of stress or mental effort a player is exerting can be learned [38].

In order to maximize the effectiveness of both traditional and physiological methods, games researchers are combining complementary techniques together in mixed methods approaches. For example, Ravaja et al. [57] combined observation and video recording techniques in tandem with the collection of GSR, EMG and EKG while participants played *Super Monkey Ball 2* (Sega, 2002). They sought to understand player reactions to game events, and reported about the changes a player's emotional state experiences during the dynamic flow of events and action. They also identified patterns in positive emotional responses that were specific to game events, giving some insight as to how a game's reward schedule operates, and how it may be a contributing factor to addictive gaming. Finally, they mention additional benefits to understanding the emotional responses of players, such as assisting in the development of therapy games for treatment of phobias, as well as generic implications for game design, as the patterns in emotional response provide information on what parts of games are the most pleasurable and attention-grabbing [57].

In another study, Nacke et al. [52] investigated the player experience of an FPS with the game audio on and off. They collected GSR, EMG, as well as the GEQ. Although their physiological data did not provide any insight, they did find there were significant effects across the dimensions of immersion, competence, tension, flow, negative affect, positive affect, and challenge. They go on to discuss that the interaction of audio on the areas of tension and flow indicates an important relationship between audio and the gameplay experience. The most pleasant condition for playing the game was with the sound on, however the positive affect of sound was dependent on the presence of music in those experiences related to tension and flow.

Researchers have been interested in the effectiveness of these mixed method approaches, and whether they are worth the extra effort when designing GUR experiments. A study was conducted using physiological measures in addition to the traditional think-aloud protocol, documenting any challenges and guidelines found when using the techniques together. Participants in the study played *Portal* (Valve Corporation, 2007) while having their physiological data and gameplay recorded, and then retrospectively talked experimenters through their thought processes while watching the footage. The physiological measures helped researchers uncover several interesting responses that were not present in the think-aloud data. Likewise, players would sometimes mention interesting experiences that were not reflected within the physiological data. Based on these results, it is recommended that researchers use both think-first and sense-first approaches in the analysis of data, and to use physiological features with think aloud reporting anchored on game events [62].

2.3.3 *Game Design, and the Player Experience*

A pressing issue in both games research and the commercial games industry is how to design games to be more immersive. Understanding various elements of the player experience can inform and improve game design. As FPS games are widely considered to be among the most immersive types of games, it follows that research has been done to discover which factors within these games contribute to this. Grimshaw et al. [26] have discussed this at length, as well as how to design for greater immersion in FPS games.

GUR has made several contributions to game design through understanding the play experience. For example, it has been shown that the death of a player's character is not a universally negative event. Research was conducted to evaluate facial expressions using EMG while players completed a game session. Indeed, the sense of challenge and progress obtained through clearing difficult portions of games was shown to be a pleasurable experience. This is not to say that player death is always positive; when progress is impossible, that sense of challenge becomes lost and dying is, of course, not fun [63].

Indeed, even the feasibility of using GUR to inform game design has been examined in depth. In addition to the previous work discussed by Mirza-Babaei [45], which focuses on already complete games, there has been some analysis into using physiological methods during the development cycle. Gualeni et al. [27] focused on casual games, and identifying points of stress and concentration. They found meaningful design implications, but also note that the positive aspects are balanced out by the invasiveness of the sensors, as well as the additional programming and analysis time and required by developers. Despite the drawbacks, they conclude that these methods do have a place within game design.

In general, players follow a cycle of perception and action. They may perceive something about the environment or status of the game, and perform some action in response. This continues constantly, and if a player is not familiar with the game being played, it is through this process that they learn the affordances of the different gameplay objects. This cycle is imperative for game designers to understand and utilize, as it allows them to effectively teach players about the game and thereby drive the gameplay forward [34]. It may also be possible that informative sound follows a similar cycle. It would follow that the sounds an object creates, or that is produced in response to some action, can give information about the affordances of that object or action. This notion gives weight to the idea that careful design of game sounds, such that they enhance the aesthetics and feedback, is an important contributor the overall UX [36].

2.4 SUMMARY

In this chapter, I have explored the literature on important topics and current areas of research within both video game audio and GUR. The role and importance of audio in games has been addressed, with a strong focus on informative audio design in both commercial and accessible games. In order to further the understanding of game audio, and in particular informative sound design, we turn to methods from GUR. The current trends in the research climate have been examined, with special detail paid to both traditional and psychophysiological evaluative methods as well as the ways that they complement each other when used in conjunction. Finally, game design and game audio design have been touched upon briefly, in order to qualify the motivation for the remaining work within this thesis.

Part II

EXPERIMENTS

3

STUDY 1: INVESTIGATING THE IMPACT OF HEALTH RELATED SOUNDS IN A FIRST PERSON SHOOTER

3.1 INTRODUCTION

For the initial experiment, the intention was to explore the notion of informative audio in FPS games and determine what effects it has on the player experience. To do this, a simple level was built in the *Unity* game engine, and provisions were made such that different elements of the game's audio could be easily changed or removed. As the health of a player character is the most critical resource in any video game, the decision was made to investigate the informative audio relating to player health. This fit in nicely with the sound design patterns discussed by Ng and Nesbitt [53], as they mention both damage and impending death and their close relation to one another.

The motivation for this study was to perform some preliminary exploratory analysis of the effects that informative game audio have on the player. By creating a game where it is specific sounds can be prevented from playing, it became possible to isolate any effects of the experimental condition to consequently be correlated to the absence or presence of the chosen audio.

Two versions of the game were built; one with all player health sounds left intact, and one completely stripped of them. Participants played both games and filled out questionnaires relating to the experience, as well as participated in an interview at the end of their session. It was discovered, unsurprisingly, that players had a much greater awareness of the level of their character's health when they were provided with health related audio cues. Additionally, they also felt more autonomous when this feedback was present. A need for auditory health related feedback was discovered, and the study provided clues to several areas for further research to further the understanding of how to effectively design and utilize informative audio.

3.2 RELATED WORK

Of the research and material discussed in Chapter 2, some of the most directly applicable is the work done by Ng and Nesbitt [53]. They discussed the concept of game audio as a tool for communicating information, and suggested a framework for considering informative sound design. In this experiment, their suggestions of impending death and damage were addressed, due to these being some of the most frequently occurring and noticeable events in typical game play. Also, Collins and Kapralos recommend that in order to design effective game audio, the focus should be on the player's character [14]. These were the main drives for choosing to study the presence and removal of health related audio cues. By researching the player experience under these conditions, it is possible to determine if these subcategories of informative game audio have any effect on a player's motivations for playing games or influence them in some way or another [69].

The questionnaires that gave the most broad view of the game experience without risking survey fatigue were the PANAS [64], the PENS [59], and the IMI [39]. This allowed for some insight into the basic levels of positive and negative affect of the participants, while the other questionnaires offered deeper insight into how their need satisfaction and intrinsic motivations changed, if at all. To complement the questionnaires, a mixed methods approach of also examining physiological data was employed. This type of experimental design has been successfully used in the past by researchers such as Nacke et al. [52] for sound related investigations, and Mirza-Babaei et al. [45] have shown that biometrics can reveal more issues relating to the player experience than traditional methods alone.

3.3 THE GAME

3.3.1 *Overview*

The game used for the study was an FPS developed by undergraduate students using the *Unity* game engine. The choice to develop the game in-house was made in order to have complete control over what audio cues played during gameplay. To this end, it was possible to disable the cues that were relevant to the study without completely muting all other sound effects.

The game supports typical FPS interactions such as running, jumping, and shooting enemies. Many design elements included in these types of games were also used, including health pickups, exploding barrels, and different types of enemies. The game consists of a single level, the goal of which is to collect six cupcakes that are scattered throughout the game world. In the event that the player runs out of health, they are sent to the beginning of the level and all of their progress is reset. The level was designed non-linearly, and in such a way that a typical play session would take the average player 10 to 15 minutes to complete, although an experienced player could finish in significantly less time.

In order to discover some of the ways that we use and process auditory information, the management of the player character's health was specifically targeted. In one experimental condition, all sounds related to the health of the player were removed, including:

- *Damage sounds*: grunting noises that occur when the player receives damage from an enemy or the environment.
- *Pickup sounds*: confirmation noises alerting the player that they have successfully picked up a health pack.
- *Low health alerts*: a continuous beeping sound indicating that the player has a low level of health.

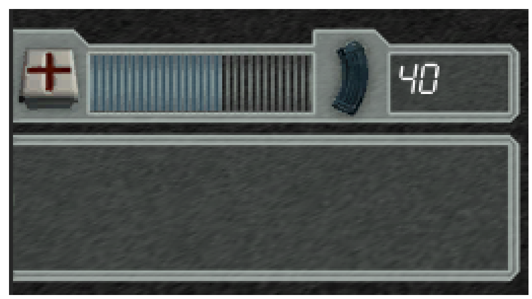
- *Death scream*: a scream of agony that occurs when the character's health drops to zero.

By removing these cues, their role in assisting the player in making decisions in-game as well as their overall importance to the gameplay experience was sought to be identified.

(a) A player finds a cupcake.

(b) Taking damage.

(c) Health packs in convenient locations.



(d) The heads-up display.

Figure 1: Study 1 Game Screenshots.

The game was designed to be difficult so that the players would experience the presence and absence of these sounds. Although there were several enemies that dealt large amounts of damage to the player, groups of health packs were generously spread throughout clear locations in the level, allowing players to use them or return to them later as necessary.

3.3.2 *Audio and Other Feedback*

When designing the game, special consideration was taken to all audio present in each play condition, and only that which was directly related to feedback for the level of health of the player character was removed. Other sounds were not changed in any way. These include the sound effects of the weapons of the player and enemies, the screams of the enemies when they are defeated, a sound that plays indicating the gathering of an objective, and an ambient background track that plays throughout the game.

The visual feedback for the game was not changed at all between experimental conditions, even that which is related to player health. A small heads-up display (shown in Figure 1d) is located in the bottom left corner, indicating the player's current health in the form of a bar, as well as the amount of ammunition remaining before their weapon needs to be reloaded. Additionally, if the player receives damage, a blood spray effect flashes around the edge of the screen (as seen in Figure 1b).

3.3.3 *Game Metric Data*

In addition to the external data that was collected (see Section 3.4.1), a framework was coded within the game itself to collect some basic gameplay data. It was decided to gather information about the total time spent playing the game, the player's position and movements, as well as how much health they had remaining and how many objectives they had collected. Each piece of data was collected each frame of the game to determine exactly where and when a player was taking damage, and allow researchers to track their movements in relation to high damaging hits. A sample of collected data follows:

```
TimeElapsed Player Direction PlayerPosition #Cupcakes CurrentHealth
88.867 (-0.654, -0.043, -0.756) (-53.351, 1.930, -35.330) 1 120
```

```
88.881 (-0.654, -0.043, -0.756) (-53.413, 1.930, -35.403) 1 140
```

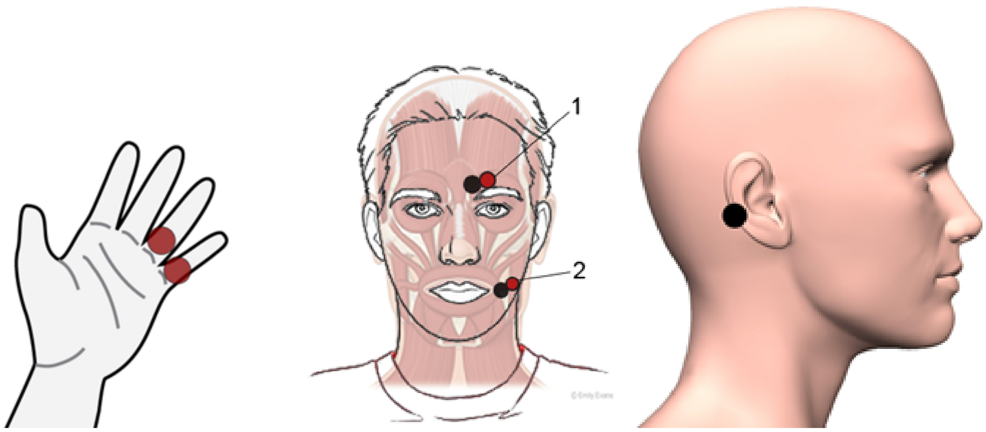
An additional heading, `System Time`, was also included in the logged data but is not shown in this example for legibility. From this sample, we can see that a participant activated a health pickup and restored 20 health at around 89 seconds into their play session. It can also be ascertained that the player did not change their direction and was moving forward at a specific place in the game world, but this is not helpful to know without an in-editor view of the game. Movement patterns were deemed only relevant over larger time spans, and while they may provide some insight as to how players experienced the level, they revealed more about level design than informative audio and were not assessed in depth.

Two more game metrics were collected indirectly: the number of deaths that a participant experienced, as well as if they successfully collected all 6 cupcakes within the level. This is due to the way the data is collected and saved. A log file is generated whenever a player's character dies or successfully collects all objectives, so the number of deaths that a player experiences can easily be ascertained by the number of files generated, and all successful attempts had a special identifier in their filename denoting that all cupcakes were collected. This information was used to determine if the presence of informative health sounds had any impact on a player's overall successes or failures in the game.

3.4 METHOD

3.4.1 *Experimental Design*

For the study, I used a game developed by students to ensure that I had the ability to alter specific audio cues. As I was interested in how the presence of these cues affected the player experience, I employed several measures used in previous studies with similar goals in measuring the player experience [52, 45]. Among these are the PANAS [64], the IMI [39], the PENS [59], as well as some basic game metrics (including current character health and number of failed attempts) and a custom set of interview questions. I also collected a suite of physiological measures, including GSR as well as EMG of the muscles on each participant's right cheek and above their right eyebrow.



(a) GSR sensor locations. (b) EMG sensor locations. (c) Ground wire location.

Figure 2: Study 1 Physiological Sensor Locations.

A within-participants study design was adopted, having each participant play both experimental conditions. The order in which each condition was presented to participants was counterbalanced to account for any possible learning effects that may have occurred due to participants becoming familiar with the positions of enemies or objectives within the level.

Participants were asked to play the game for 10 minutes in each session, followed by an administration of the questionnaires. At the end of the procedure, audio was recorded of the participant answering more in-depth interview questions. This allowed for the opportunity to assess whether the participant was aware of the change in audio cue presence, as well as discuss their thoughts and feelings regarding their effectiveness and design.

3.4.2 *Participants*

Data was collected from a total of 26 participants (11 female) that were attending the University of Ontario Institute of Technology (UOIT). Unfortunately, the data from two of those participants was discarded due to their inability to finish the experiment, leaving a total of 24 usable participants (10 female). The age of the sample population ranged from 18 to 32 years old ($M = 21.96, SD = 3.43$). Participants were enrolled in the study voluntarily and did not receive any compensation for their participation.

Many of the participants were experienced with video games in general (using a 7-point Likert scale where 1 is inexperienced and 7 is experienced, $M = 6.08, SD = 1.06$), and familiar with FPS games ($M = 5.04, SD = 1.65$ using the same scale). No participants reported being unfamiliar with games, although 4 reported that they did not play FPS games often.

When asked to estimate the number of hours per week they played video games, responses were much more varied. Participants reported spending anywhere from 0 to 35 hours of video games per week on average ($M = 16.25, SD = 9.94$), with only 1 participant claiming to play 0 hours per week currently. From these demographics, it can be reasonably assumed that all participants are familiar enough with video games to understand and have some experience with common feedback mechanisms, and therefore be able to provide useful insight for the experiment.

While participants were not explicitly screened for hearing disabilities in this study, none reported being unable to hear any of the sounds in the game, including those that were added or removed as part of the experimental condition. Therefore, it is unlikely that the possibility of hearing disabilities had affected the results in any way. In the following studies, the demographics questionnaires included an item related to hearing disabilities to further ensure validity of the results.

Furthermore, no participants reported being trained as musicians or sound designers, and therefore all were treated as casual listeners, rather than professional ones.

3.4.3 *Experimental Environment*

The experiment took place in the Game Science Lab at UOIT. Due to the nature of the physiological sensors, only one participant was ran at a time. The Game Science Lab was set up to mimic a typical video game playing environment as closely as possible in order to make participants feel at home and thereby limit artifacts in the physiological data due to nervousness or other discomfort. Participation in the study was limited to a single session, and no participants were required to perform any activities outside of the duration of their session. No additional materials were required of participants, and an experimenter was in the room with them at all times, behind a cubicle wall separating the play area from the data collection area.

3.4.4 *Data Management*

Two separate computers were used in conducting the experiment. One managed the collection and recording of the physiological data, while the other ran the game itself. The game metric data was therefore collected on the second computer. After each experimental session, both physiological data and gameplay metric data were moved to a secure external hard drive that was stored in the UOIT Games and Media Entertainment Research Lab (GAMERLab). Filenames for each participant's data were anonymized after the data was collected, using a common participant number identifier rather than a name of any kind.

Questionnaire results were collected through the use of an online form, and much like other data, were identified only by a participant number identifier. At no point were the names of any participants entered to any online forms. The results of these questionnaires went to the experimenter's own private online storage account and were not shared with anyone that was not involved in the analysis of the data.

Interviews with participants were recorded digitally through the use of a mobile device and synced to the private account of the experimenter. Although participant numbers were still used to identify the file names, in order to protect the anonymity of the participants all interviews were transcribed personally by the experimenter so that no one else would hear the voices of participants and possibly identify them.

3.4.5 *Procedure*

Before the experiment began, participants were welcomed to the laboratory and briefed on the procedure. Consent was obtained after explaining the methods of data collection and any equipment used that the participant was unfamiliar with. Once they had no further questions, participants were asked to fill out a demographics questionnaire. Physiological sensors were then attached to the participant- the proximal phalanges of their ring and pinky fingers of their right hand were used to measure GSR, and pairs of EMG sensors on the corrugator supercilii (above they eybrow) and the zygomaticus major (cheek) to measure muscle activity. A grounding sensor was also attached behind the right ear of the participant, as it requires a bony area with no muscle activity. These sensor locations can be seen in Figure 2. After assuring that the sensors were properly affixed and that the participant was comfortable, a 5 minute baseline measurement was taken as the participant relaxed and focused on a neutral image. Following this, the game itself was introduced, and it was made sure that participants understood the controls and goals of the game before proceeding to a 60 second trial. Assuming no major issues had arisen and that the participant was confident that they understood the controls and objectives, the game was restarted and the first experimental condition began. Participants played for up to 10 minutes or until they finished the game, whichever occurred first, while their physiological data was recorded. When the first session was over, participants were instructed to fill out a set of surveys including the PANAS, IMI, and PENS, as well as a few questions related to their experience (see Section A.6). Afterwards, the gameplay recording and survey steps were repeated for the next and final play session, of the second experimental condition. Finally, participants were assisted in removing their sensors and a brief exit interview was conducted and recorded for analysis.

3.5 RESULTS

The results of the experiment are detailed below, sectioned into four different categories. First, the results of each questionnaire are described, followed by physiological data and game metrics. Finally, trends in responses to the interview questions are discussed. For ease of distinguishing experimental conditions, results from the condition without health related sounds are denoted NoSound (NS), and those from the condition including health related sounds are denoted Sound (S). All measures that have satisfied parametric assumptions have been evaluated using a paired samples t-test, and those that violate parametric assumptions have been evaluated using a Wilcoxon signed ranks test, unless otherwise noted.

3.5.1 *Survey Data*

Survey results have been further divided into subcategories relating to each questionnaire that was implemented in the evaluation.

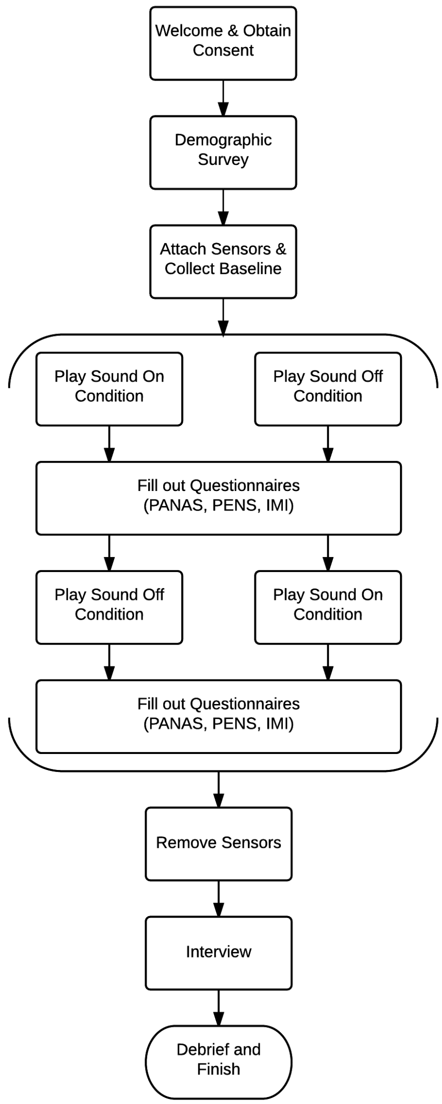


Figure 3: Study 1 Procedure

3.5.1.1 *PANAS*

The data for positive affect satisfied parametric assumptions, while the data for negative affect did not. Survey results for positive affect showed that on average, participants had similar levels of positive affect when playing without health related sounds ($M_{NS} = 30.79, SD_{NS} = 8.98$) and when playing with health related sounds ($M_S = 31.08, SD_S = 7.26$). Likewise, there were similar levels of negative affect when playing without health feedback sounds ($M_{NS} = 15.12, SD_{NS} = 1.18$)

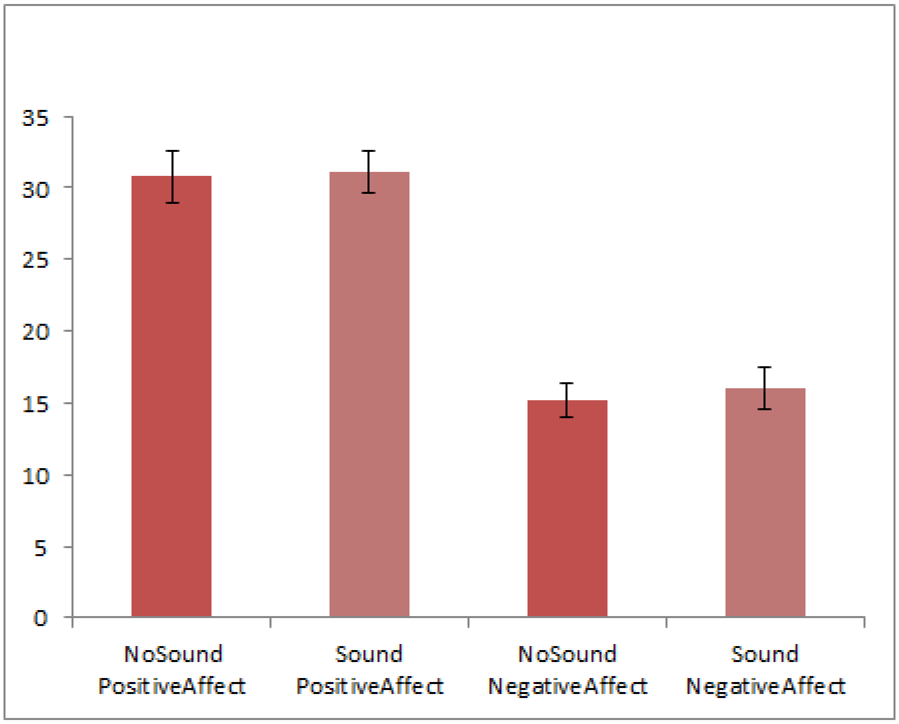


Figure 4: Study 1 PANAS Means

and with health feedback sounds ($M_S = 16, SD_S = 7.20$). On average, participants experienced much higher levels of positive affect than negative affect.

3.5.1.2 *IMI*

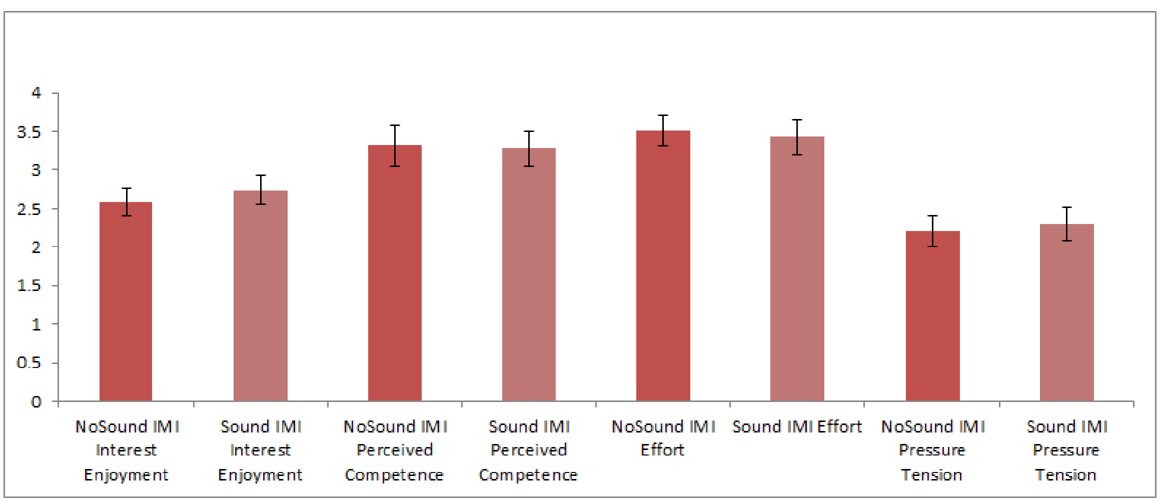


Figure 5: Study 1 IMI Means

All subscales for the IMI satisfied parametric assumptions, except for the Pressure/Tension scale, which is not normally distributed. Players reported similar levels of interest and enjoyment when playing without ($M_{NS} = 2.58, SD_{NS} = 0.92$) and with ($M_S = 2.74, SD_S = 0.90$) health related sounds. Likewise, the perceived competence of our participants showed no significant difference when playing without ($M_{NS} = 3.32, SD_{NS} = 1.30$) or with the sounds ($M_S = 3.28, SD_S = 1.08$). Participant effort was also similar between absence ($M_{NS} = 3.51, SD_{NS} = 0.99$) or presence of sounds ($M_S = 3.43, SD_S = 1.14$). Finally, pressure and tension felt by participants were also quite similar when playing without health related sounds ($M_{NS} = 2.21, SD_{NS} = 0.95$) and with them ($M_S = 2.30, SD_S = 1.06$). Remembering that the maximum possible score of any of these subscales is 5, it is possible to ascertain that participants experienced moderate levels of interest or enjoyment, as well as pressure and tension. Furthermore, they felt that they performed above average in terms of their competence at the game, and had to exert a moderate to high level of effort to achieve this.

3.5.1.3 *PENS*

Of the PENS results, the subscales of Competence, Relatedness, and Intuitive Controls were normally distributed, whereas Autonomy and Presence were not. In terms of perceived player competence, participants felt that they performed reasonably well without auditory health feedback ($M_{NS} = 3.36, SD_{NS} = 0.98$) as well as with it ($M_S = 3.46, SD_S = 0.88$). Similarly, players did not feel much relatedness in either the NoSound ($M_{NS} = 1.85, SD_{NS} = 0.74$) or Sound ($M_S = 1.94, SD_S = 0.71$) conditions. The controls for the game were perceived as intuitive no matter whether health sounds were absent ($M_{NS} = 3.99, SD_{NS} = 0.60$) or present ($M_S = 3.93, SD_S = 0.61$). Players also felt almost no difference in presence between playing without health sounds ($M_{NS} = 2.05, SD_{NS} = 0.88$) or with them ($M_S = 2.11, SD_S = 0.78$).

However, in terms of feeling autonomy, it has been shown that between playing without health sounds ($M_{NS} = 2.24, SD_{NS} = 0.85$) and playing with them ($M_S =$

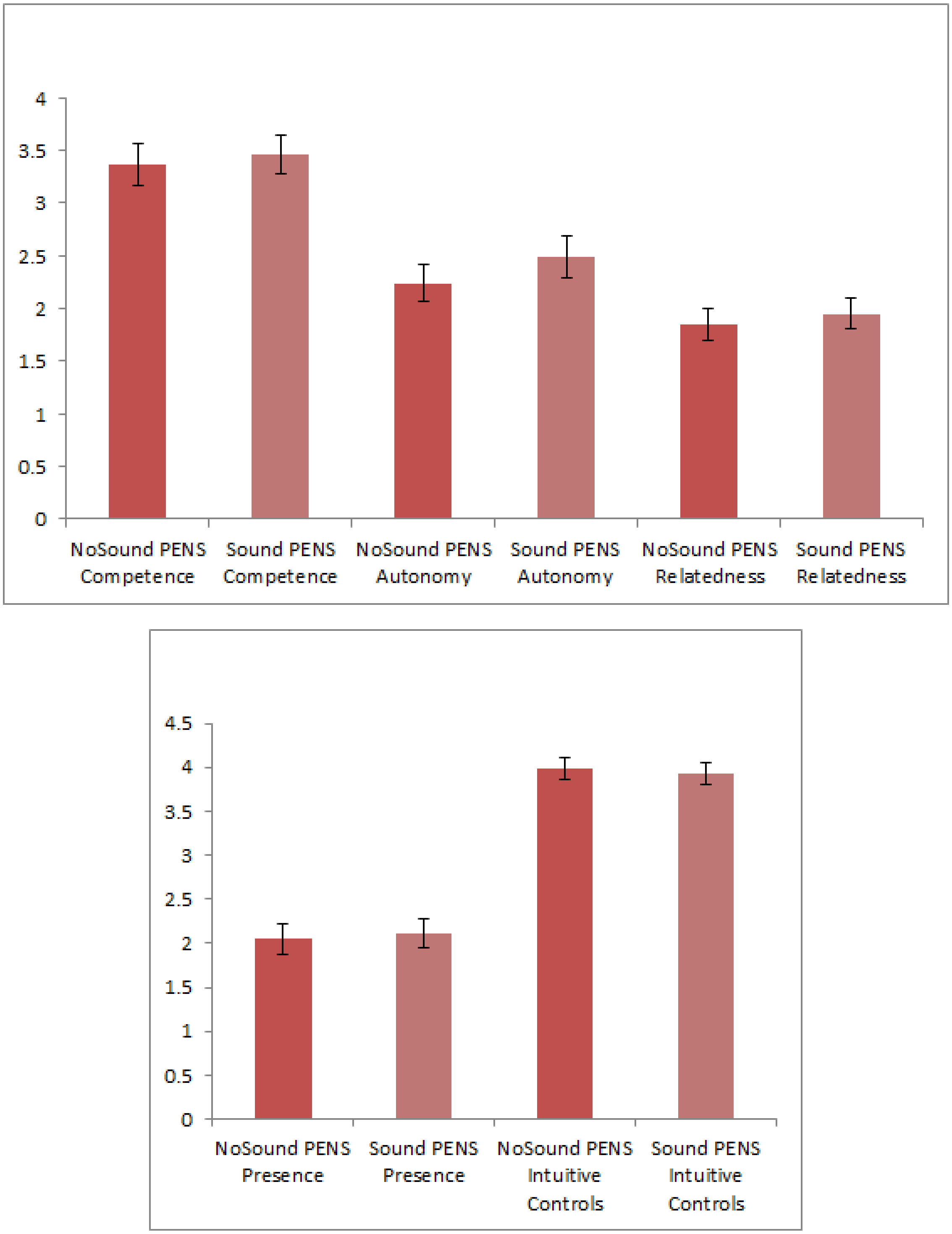


Figure 6: Study 1 PENS Means

$2.48, SD_S = 0.98$), $z = -2.004, p = 0.045, r = 0.409$ there is a significant effect shown.

As with the IMI, the maximum score in any of these subscales is 5. Unsurprisingly, the slightly above average scores for perceived player competence match the results from the IMI. Participants also felt that the controls for the game were intuitive. Despite this, they also felt that the game world was not relatable and did not feel present in it, although they did feel moderately autonomous.

3.5.1.4 *Other Questions*

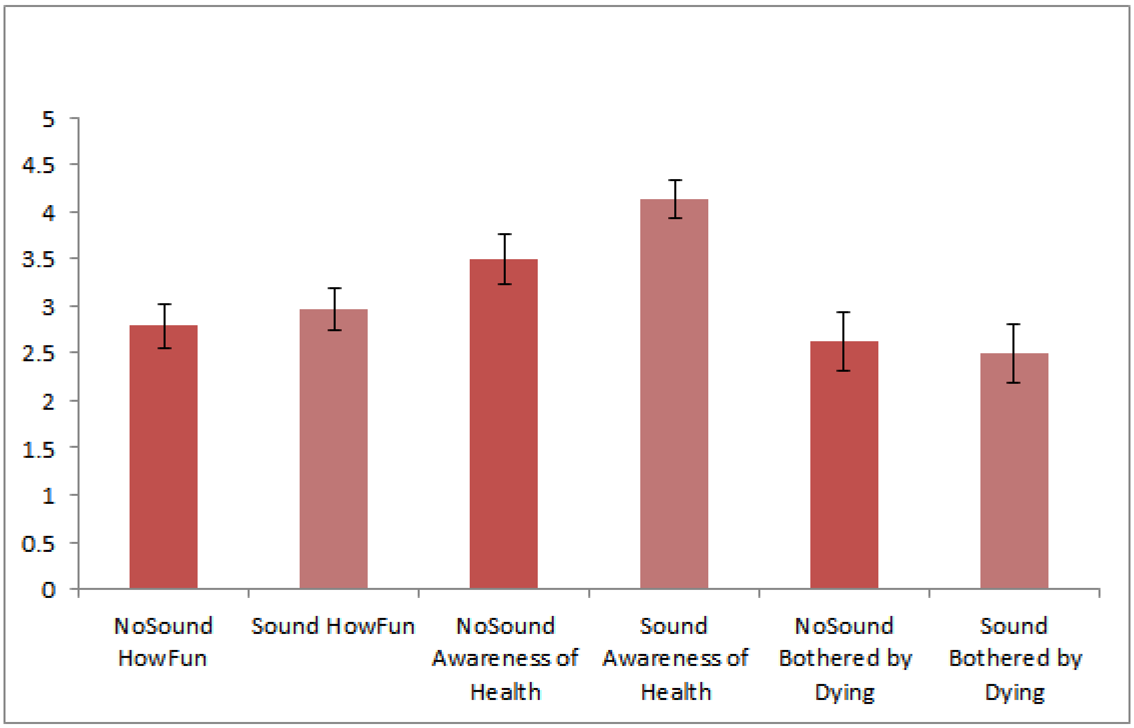


Figure 7: Study 1 Additional Question Means

The additional questions that were asked (See Section A.6) also showed some interesting data. The data for all three questions violates parametric assumptions. When asked how fun the game was, participants did not find the game with health related sounds($M_S = 2.96, SD_S = 1.08$) much more fun than without ($M_{NS} = 2.79, SD_{NS} = 1.14$). Likewise, dying in the game bothered them nearly equally when playing without sounds ($M_{NS} = 2.63, SD_{NS} = 1.50$) and with ($M_S = 2.50, SD_{NS} = 1.50$).

Perhaps unsurprisingly, participants did find that they were significantly more aware of their health when playing with informative health sounds($M_S = 4.13, SD_S = 0.99$) than without ($M_{NS} = 3.50, SD_{NS} = 1.29$), $z = -2.470, p = 0.014, r = -0.504$.

As the maximum scores in all possible areas are 5, it is evident that, overall, players felt that the game was moderately fun and were only slightly bothered by dying. When playing without informative health sounds, players had a slightly above average awareness of their level of health, but when playing with them, they experienced a high level of awareness.

3.5.2 *Physiological Data*

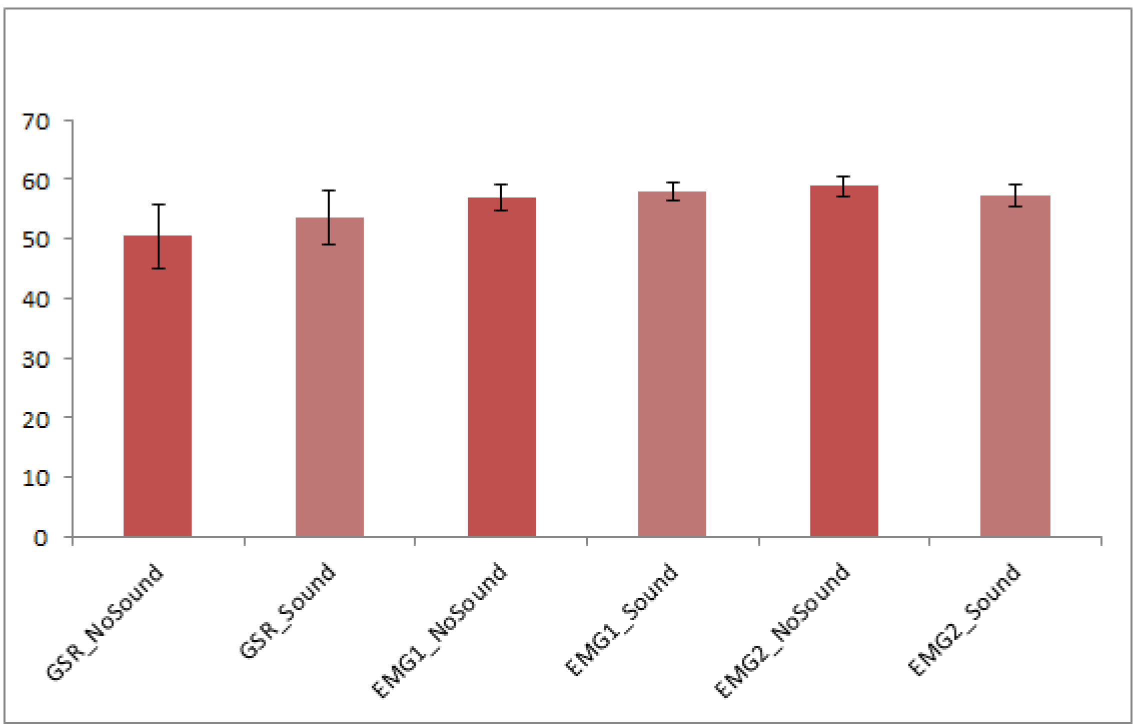


Figure 8: Study 1 Physiological Means

Of the physiological measures collected, the data from the GSR satisfies parametric assumptions while both channels of EMG collected do not. On average, participants experienced moderate levels of arousal both when playing without informative health sounds ($M_{NS} = 50.46, SD_{NS} = 26.72$) and with them ($M_S =$

53.62, $SD_S = 22.16$). The activation of their corrugator supercilii was slightly below 60% over the course of both the NoSound ($M_{NS} = 56.96, SD_{NS} = 10.97$) and Sound ($M_S = 57.96, SD_S = 7.08$) conditions. The same is true for their zygomaticus major, showing little difference between playing without ($M_{NS} = 58.79, SD_{NS} = 7.73$) and with ($M_S = 57.42, SD_S = 8.95$) health related audio.

As a percentage of maximum level of arousal or muscle activation, the data shows that the arousal level of participants varied greatly across a given play session, due likely to peaks of intense gameplay and periods of time where no enemies were present. The activation of both facial muscles was also slightly above average in both cases, although there was comparatively little difference in facial activity.

3.5.3 *Game Performance Data*

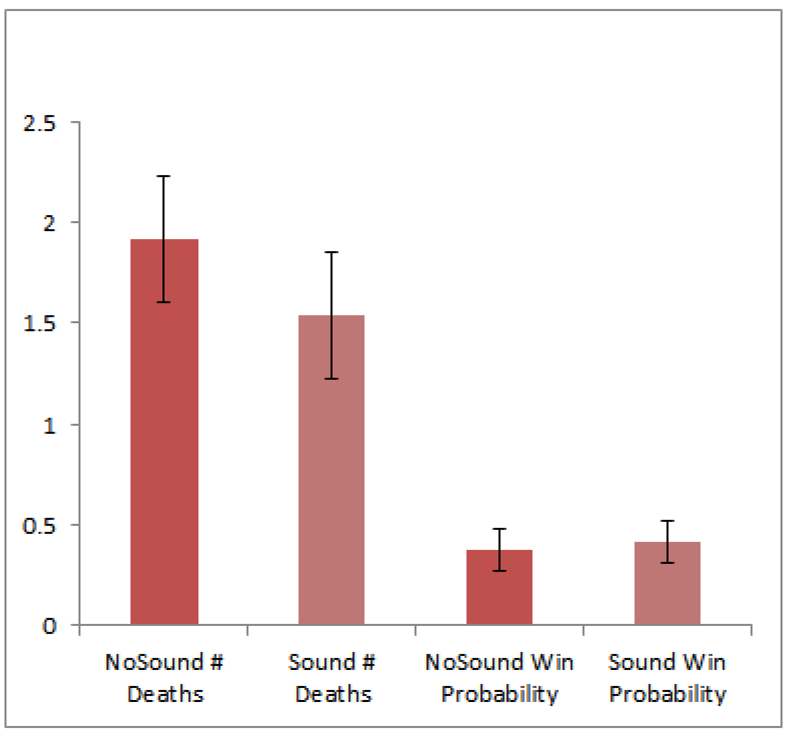


Figure 9: Game Metric Means

The main factors of interest in examining the gameplay data were the number of successes that occurred and failures that participants had throughout their play session. A failure was characterized by a player's health reaching zero and having to start over, while a success occurred when a player collected all 6 objectives within the 10 minute time limit.

When playing without health related sounds, the number of failures a participant experienced ranged from 0 to 6 ($M_{NS} = 1.91, SD_{NS} = 1.53$), compared to a range of 0 to 5 when playing with them ($M_S = 1.54, SD_S = 1.53$). A total of 9 participants (38%) successfully completed the game with health sounds turned off, and 10 (42%) had success with them on. Of these, only 5 (21%) participants completed both conditions successfully before running out of time.

3.5.4 *Interview Data*

Interviewing participants at the end of the experiment proved to be a valuable source of information for future study. When asked if they could tell the difference between the play sessions, 16/24 participants (67%) identified at least some of the sound differences, with 6/24 (25%) correctly identifying all changes. Many participants (13/24, 54%) felt that neither session was more difficult than the other, but 7/24 (29%) felt that the game was more difficult without the presence of health related sounds, and the remaining 4 (17%) felt that having those sounds actually made the game feel more difficult. All participants commented on the importance of audio cues in games, citing reasons from informative feedback to increasing immersion and simply sound as a reward mechanism.

When asked how the change in sound made them feel, participants had many things to say, although 5 (21%) mentioned that not having any sound for health feedback was frustrating. Less than half (10, 42%) of participants did not mention audio at all when asked how they judged whether they were near death in a game, mostly citing visual cues such as hit flashes and health bars. Some of the reasons cited when asked if and why audio health cues were important include things like needing to focus on the gameplay and not the health bar, and learning how much damage you can take before needing to get health pickups.

In terms of what kinds of sounds the participants would like to hear to denote a low level of health, 9 (38%) mentioned that they would prefer some sort of realistic sound, such as heavy breathing or a heartbeat sound. On the other hand, another 9 (38%) said that they would prefer a more abstract kind of sound, not unlike the beeping that was actually used in the game. The remaining 6 (25%) either had no preference or said that it would depend on the context of the game.

When asked about changing the volume of a health alert sound based on a player's level of health, 10 (42%) disagreed, saying it would be a bad idea. Another 9 (38%) thought that increasing volume at lower levels of health could be helpful while the remaining 5 (21%) said that it would depend on the context of the game. Participants were much more interested in changing the frequency of the alert sound based on the level of health. Of 16 (67%) that were in favor of the idea, 13 (54%) thought that the frequency should increase as health became lower, while 2 (8%) thought that the frequency should decrease as health became lower. The final person (1, 4%) elaborated that the frequency should increase if an abstract beeping sound is used, but decrease if the sound is more realistic, like a heartbeat. A further 6 (25%) had no opinion or mentioned it being context dependent. Only 2 (8%) thought that frequency should not be dynamic in some way.

3.6 Discussion

Much information can be gained from this exploratory study. First and foremost, the lack of statistical significance related to any of the physiological data as a result of altering game sound echoes the results obtained by Nacke et al. [52], and is not surprising. It is possible that significant results could be obtained by doing an event based analysis rather than examining the physiological activity over an entire play session. It stands to reason that over the 10 minute sessions we ran, a relatively small amount of time would be spent actually experiencing health changing events. In addition to this, it was noticed that some players may have involuntarily tensed up their facial muscles during intense moments of gameplay, not necessarily in relation to a change in their health, which could also have caused some confusion in the readings. Indeed, it would seem that a more in depth event based analysis will be necessary to fully understand some of the physiological reactions to informative game sound. In the future, it would also be helpful to design an experiment in which the researchers have more control over when and how these health related events occur, rather than leave it up to the chance of it emerging in gameplay. This would account for players of all skill levels and offer a more complete picture.

The significance found in the autonomy subscale of the PENS is intriguing. This could indicate that informative health audio plays some role in the amount of agency that a player feels when playing an FPS game. This may be linked to the other significant results, as players are more aware of their currently level of health, and thus their capabilities, they may feel more freedom to explore the game world in different ways or change their style of play based upon their perceived level of danger. This is simply conjecture, and would require more in depth examination. Before work could even begin on this notion, a follow up study would first need to be done in order to confirm the effects of informative health audio on a player's sense of autonomy.

The levels of affect experienced by participants are unsurprising. In general, it is suggested that a normal population will experience higher levels of positive affect than negative affect [64]. Additionally, the nature of the experiment may have contributed to this, as it involved playing a game.

The interviews performed with participants gave way to a great amount of insight into players' feelings regarding both audio in general and informative health audio. First, although those who were explicitly frustrated about the lack of health audio were in the minority, they all felt passionately about the issue, as can be seen here:

> *"It's so frustrating; I actually make my brother sit in the room with me telling me where things are attacking me and if my health is low."*
>
> *-P12, describing other games without health cues*

Even those that did not explicitly mention being frustrated were at least disappointed with the lack of feedback.

> *"I realized that I had become reliant on the low health sound."*
>
> *-P24*

> *"I wasn't quite understanding why I wasn't getting the warning that my health was low."*
>
> *-P23*

This speaks to the need for some sort of audio based feedback for player health. The next step is to determine the ideal types of sounds that will both properly alert the player as well as be somewhat pleasing to the ear. Many participants criticized the constant beeping sound used in the experimental game, referring to it as annoying and, after a time, redundant. If a player has a low level of health for a long period of time, that may be because they are unable to currently reach some means of restoring that health, not necessarily that they are unaware or otherwise have forgotten about their near-death status. At this point, it may begin to seem to the player as if the sound is not meant to inform them of some condition, but rather punish them for poor play.

The fact that participants are almost completely evenly split about what kind of noise they would want to hear for this speaks to a need for further examination. Many participants simply mentioned alert noises that they were familiar with, or that the type of games they usually played implemented. Additionally, some participants mentioned that they did not have an outright preference, but that the "proper" sounds to use were dependent on the context of the game. This will be an important factor to consider moving forward beyond simply examining whether sounds like high-pitched beeping or heavy breathing and heartbeats are universally better to use. Tentatively, these have been categorized into *abstract sounds*, and *non-abstract (realistic) sounds*. A further study will be performed in order to work towards a proper definition for these. For now, it will be assumed that any sound that is abstract does not have a physical source within, and may not fit the aesthetic or narrative of the game itself, whereas a sound that is non-abstract will have a source within the game world and fit into the context or narrative of the game. For more information on these, and the work performed towards building a taxonomy of these sounds, please see Chapter 4.

Very clearly, players felt more aware of their character's level of health in the play session where the auditory feedback was present. This result is expected, as even at the surface, a high pitched noise will draw the listener's attention to whatever it may be signifying. However, a deeper reasoning for this may be alluded to within the interview data. Many participants mention having to pay attention to multiple things at once in a fast-paced game environment. For example:

> *"I don't look much at the health bars because I'm trying to focus on the game."*
>
> *-P4*

Other players agreed with this idea, some mentioning that they are not adept at focusing on more than one thing visually, or that it's helpful to hear a sound that is not applicable to the current action to let them know that something is wrong. This could indicate that the informative audio feedback is easing the cognitive load of some players, allowing them to process a greater amount of information by splitting the load between the auditory and visual senses.

Of those participants that gave numerical and non-context dependent answers to the question of how low a player's health should be before an alert noise is played, responses averaged to 26.17% of the total health. From this, we can safely conclude that the majority of players would feel comfortable receiving a low-health warning when they have around 1/4 of their health remaining. This would give them ample time to correct any rash actions they are performing and seek out a safe place with a method of restoring their health before their character dies.

From what has been learned from this experiment, it is possible to piece together some preliminary design recommendations for the development of informative audio in FPS games.

3.6.1 *Towards Design Recommendations for Informative Game Audio*

As the results from this study require follow-up, confirmatory studies, the design recommendations outlined here should be considered as points to begin the dialogue about improving informative health audio. The following studies in this thesis will attempt to expand upon them as more knowledge is gathered.

- *Provide players with a clear auditory indication that they are being damaged*. This may seem self explanatory, but some participants mentioned during their interview that the games they were familiar with did not offer any auditory feedback related to their health. It may not even be necessary to provide some sort of alert sound; as with earcons, the background music or other ambient audio could be altered in some minor way to give the player a hint that something within the game state has changed [53]. Although players may have difficulty understanding the meaning right away, it allows the player to plan more effectively for upcoming danger. It may even prevent some artificial difficulty caused by a player's ignorance of their character's status.
- *Alert players of impending death between 25% and 35% health*. Without any clues to the usefulness of this threshold, participant interviews seem to suggest that the preferred level for signaling low health is around 26%. Until some

usability studies have been run to determine a more concrete number, it should be recommended that the alerts be triggered within this window, so as to give the player enough time to react before getting into a certain-death scenario, but not so early as to cause unnecessary panic or annoyance.

- *Try to offload information to audio cues*. Some participants mentioned that having auditory feedback allowed them to focus on the gameplay. By identifying appropriate information that can easily be conveyed with sound, it may be possible to increase a player's satisfaction by allowing them to remain in flow. Breaking concentration to check on one's resources in the middle of frantic and intense gameplay can make the difference between a win and a loss. By giving the players the ability to learn to listen for and react to these cues, we give them more opportunities to improve their mastery of a game.
- *Involve members of the sound team in early design sessions*. Finally, many respondents have said that many styles of auditory cues can be effective, but the context, aesthetics, and design of the game play a large part in determining their effectiveness. By having even a single member of the sound team attend design and concept meetings, it could become easier for a game company to design more effective sounds that fit perfectly within a specific game's narrative. This echoes Lord's [36] view that an important part of a game's UX is to design sound and music to affect aesthetics, feedback, and rewards for players.

3.6.2 *Validity Limitations*

There are several possible validity limitations of these results that must be kept in mind. First, it is possible that internal validity was limited because of the non-dynamic nature of the game as well as the within-participants design of the study. Since the game and the location of its enemies and objectives did not change from one play session to another aside from the addition or removal of health related audio, it is possible that some learning effects came into play. The level itself was not expansive, and players would have had the opportunity to learn the locations of the objectives and threatening areas. This would allow them to develop dominant strategies over the course of their first playthrough and use that information in the second. Despite this, condition order was counterbalanced across the sample population so the majority of these effects should be mitigated.

External validity may also be called into question. The sample was taken from primarily undergraduate and graduate students at UOIT, all of whom had experience playing video games. As such, it may be difficult to generalize the results towards all gamers, however the nature of the study and its motivations target experienced gamers by design. Those who play casually may not be able to make as much use out of informative audio, by either not recognizing it for what it is, or, much like earcons [41], requiring a significant amount of training to understand the meaning of the sounds. Furthermore, by focusing the study on those high level players, it was possible to gain much deeper insight into the nature and types of audio; perhaps something a novice player might overlook or not comprehend.

3.7 CONCLUSION

Through this experiment, I was able to gain some general insight towards developing better informative audio feedback in FPS games. Several aspects of the experimental results were discussed, as an explanation was sought for some of the more unexpected results.

It was determined, however obvious it may have been, that the presence of health related audio is beneficial to players, allowing them a much greater understanding of their level of health throughout a game session. A preferred threshold for receiving low health warning was also discovered through respondents.

Most importantly, a basic framework for some informative audio design guidelines was developed, and will be expanded on and reworked throughout this body of work as new information is gathered. To that end, many avenues for further research were also discovered. Even based upon these preliminary results, the possibilities for clarification and new study extend well beyond the scope of this thesis.

3.8 future work

Many of the areas of interest within this study need to be more thoroughly examined in additional studies with more targeted objectives.

First, it would be useful to do a more in depth analysis to determine if there are indeed any physiological reactions related to the presence or absence of different categories of audio. This would require time, as the analysis of the data would need to be based upon specific game events small time windows around them, rather than examining the play session as one single unit. By breaking the gameplay down into only the events that we are interested in, it would be easier to pinpoint if those events or cues affected a player's physiological signals in any way. Looking at small frames of time would assist in preventing any subconscious muscle movements from muddling the data on a larger scale. By doing this, it would be possible to finally being understanding what elements, if any, of game audio and gameplay events trigger a physical response within players.

Second, a usability study could be performed to objectively determine the optimal health threshold for triggering a near-death alert. As the data gathered in this study was mainly from high level video game players, it would be more beneficial to determine what values worked optimally for the casual to average player.

In this study, there was no change in game difficulty to account for differing levels of gaming experience of participants. This may be worth exploring in the future to gain more specific insights about how each skill level experiences and uses auditory informative feedback differently. This could lead to a more refined set of sound design guidelines, providing suggestions based upon the game developer's target audience.

The proposal of design recommendations opens many avenues for further research. Countless studies could be performed in order to validate and expand upon the points that have been put forth in this study. It would be especially beneficial to perform a case study of independent game companies throughout the development of new games, to understand the design contribution and involvement of the sound team. This would allow for better recommendations related to their place in the development cycle and possibly even promote better interdisciplinary communication.

Finally, the notion of abstract and realistic audio in games should be examined in closer detail. By creating a taxonomy of these sounds, they can become tools to use in conjunction with the design recommendations already put forth, to strengthen them and provide more direction to anyone trying to make use of them. These definitions will be explored further in Study 2.

3.9 Summary

In this chapter, the first of three studies was detailed. A total of 24 participants played a 10 minute game twice- once with and once without the presence of player health-related auditory feedback. It was discovered that there were significant differences in both the players' awareness of their current level of health as well as their perceived level of autonomy within the game. Through interviews with participants, it was discovered that many of them felt that they did not consider auditory feedback when keeping track of their character's health, although they were almost unanimous in their opinion that audio feedback was important, citing things like pickup noises and the affordance of the ability to focus more completely on the gameplay.

The results of the experiment lead to the development of four informative sound design recommendations as well as several interesting avenues for future research, some of which are covered in the remainder of this thesis.

4 STUDY 2: CLASSIFYING ABSTRACT AND NON-ABSTRACT GAME SOUNDS

4.1 INTRODUCTION

Study 1 provided some information about how informative health-related audio does, and does not, affect players of FPS games. One of the results that stood out was that, despite having a sample of entirely proficient gamers, there was an almost even split between them based upon what type of informative health sounds they would prefer to hear. This lack of consensus was unexpected and warranted further exploration.

To deeper investigate the usefulness and player preference for these sounds, it became necessary to classify them under some form of taxonomy. No existing definitions of sound categorizations seemed to perfectly fit the things that players were reporting, thus they were referred to as *abstract* and *non-abstract* (or *realistic*) sounds.

To determine that these classifications were sensible and accurate, I sought out the opinions of professionals in game design and game audio; those who have worked in commercial games development in either an audio or game design role. The study detailed in this chapter is a short interview with some of these professionals, to determine their viewpoints on how to define *abstract* and *realistic* sounds, what qualities characterize them. It was further discussed whether there were preferential or even optimal situations in which one type of sound had a clear advantage over the other.

4.2 RELATED WORK AND MOTIVATION

The main motivation for this study was to find better definitions for abstract and realistic sounds, concepts that came from the interview results outlined in the previous chapter. Participants identified different types of sounds that they felt that they would prefer to hear for informing them of health-based information. However, there was not a consensus as to which sounds would be more preferable. Most of the examples given could have been classified as *diegetic* (the source of the sound exists within the game world) or *non-diegetic* (the source of the sounds does not exist within the game world) sounds; however responses also indicated that the degree of diegesis was not necessarily the reason for participants' preference.

To understand this, different existing classifications of game audio were examined. In Chapter 2, it can be seen that Collins has defined game audio in terms of its participatory nature [13]. While these definitions include diegetic and non-diegetic provisions and subcategories, they do not fit well with the different sounds suggested by participants in Study 1. Furthermore, feedback-related audio can fit within the scope of adaptive, dynamic, and interactive audio.

Many of the different kinds of environmental information outlined by Mountford and Gaver [47] are applicable to the player health sounds that were examined, but do not categorize the responses obtained into distinct groups, and do not account for the diegesis of the proposed sounds.

It became clear that while existing work and definitions account for various aspects of the proposed health feedback audio types, that there was not an existing formal taxonomy that would easily and concisely categorize them into high level groups for analysis. Therefore, the notions of *abstract* and *realistic* game audio are suggested. To determine whether the names of these categories are intuitive, and to determine what exactly makes a game sound abstract or realistic, individuals with professional experience in game design or game audio were approached for their thoughts and opinions.

4.3 METHOD

4.3.1 *Experimental Design*

Since this study was conducted to gain more information about defining and categorizing certain types of sound, an interview with participants was chosen as the most appropriate form of investigation. Rather than measuring a change in variables, the interest of this part of my work was to determine if there was a consensus among game design and audio professionals as to what attributes made a game sound abstract, or realistic. I contacted willing participants through Skype, and with their permission, recorded a semi-structured interview with each of them (see Section B.2). Interviews lasted typically 30 to 40 minutes, and were then transcribed into text and coded by both the experimenter and a research assistant.

Responses were analyzed for elements of how each participant defined both *abstract* and *realistic* game audio. Then, any examples given were coded using a 2-stage process: first, whether the example given fell under that participant's definition of abstract or realistic audio, and second, whether the game event described would be viewed as a positive, negative, or neutral event from the player's perspective.

4.3.2 *Participants*

Interview data was collected from a total of 5 participants, aged between 26 and 28 ($M = 26.60, SD = 0.89$). All participants were experienced in playing games (Using a 7-point Likert scale where 1 represents little experience and 7 represents much experience, $M = 6.40, SD = 0.89$), reporting that they played an average of 13 hours per week, with no one playing less than 10 hours per week.

Four of the participants were also moderately experienced with game design, either currently working or having previously worked in the games industry in some professional capacity (On a 7-point Likert scale, where 1 represents little design experience and 7 represents much experience, $M = 4.20, SD = 1.92$). Additionally, no participants reported having any hearing impairments, which may have affected the results in some way if any were present. Participants were once again enrolled voluntarily and were not compensated for their participation.

4.3.3 *Experimental Environment*

The study was conducted over Skype, so participants were able to participate from the comfort of their own home computing environment. Participants were informed that they were able to interrupt and leave the study at any point in time. All interviews were conducted one-on-one, without any intermediaries. Additionally, participation was limited to a single call session; no participants were required to perform any study-related tasks outside of the appointed interview time. As in the previous experiment, no additional materials were required by the participant, and neither party left the Skype call for the duration of the interview.

4.3.4 *Data Management*

Participants completed demographic surveys using an online form, and were only identified by a participant number to keep their identities anonymous. The results of the survey were sent to the experimenter online and were not shared with any other parties.

All recorded audio was stored on an encrypted hard drive and kept in the UOIT GAMERLab. The files were generated by a third party Skype call recorder, *MP3 Skype Recorder*, and renamed to participant identifiers immediately after the calls were completed. Prior to any data analysis, each recorded call was transcribed in full to text form to further protect the identities of the participants. In other words, the experimenter was the only person listening to the recorded voices of the participants.

4.3.5 *Procedure*

Prior to beginning the Skype call, participants were thanked for their time, and the consent process was explained to them. After obtaining consent, participants were instructed to complete a short demographics survey using an online form. Once both parties were ready to begin, the voice call was initiated and the recording software activated. Before the interview began, the consent process was once again explained to the participant, to maintain a record of their voluntary participation. From there, the interview began and a semi-structured question outline was followed (see Section B.2). Once concluded, the interview was closed by thanking the participant and answering any questions that they may have had about the motivations for the study.

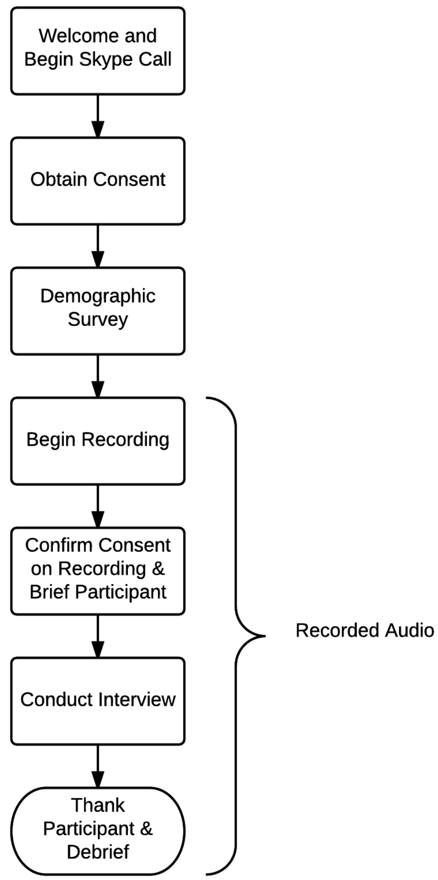


Figure 10: Study 2 Procedure

4.4 RESULTS

As mentioned previously in the chapter, all interviews were coded by 2 separate individuals, the experimenter and a research assistant, in order to ensure inter-rater reliability. Each participant's responses are detailed below as per the interpretations of the coders. Results are organized such that each participant's definitions of the types of sounds are detailed first, followed by any interesting patterns in their given examples, or other noteworthy responses.

4.4.1 *Participant 1*

The first participant interviewed focused primarily on the idea of player-centric sounds. In general, an abstract sound was a noise that was unnatural for the source of the sound to make, whereas realistic sounds were noises that were natural for the source. They elaborated, saying that abstract noises were generally not related to the player character, and were instead things like notification noises or other background sounds. Conversely, events that happened to or in relation to the player character, such as receiving or inflicting damage, were realistic. These were described as "Concrete, player-relevant sounds."

Of the examples provided, all four relating to abstract sound could be described as a neutral game event, such as notification sounds or non-speech dialogue with other characters. On the other hand, most of the examples provided for realistic sounds (4 of 5) were related to either distinctly positive or negative game events, such as taking damage, or the sounds that containers make when being looted for items.

Abstract Positive	Abstract Neutral	Abstract Negative
0	4	0

Table 1: P1 - Number of Abstract Sound Examples

Non-Abstract Positive	Non-Abstract Neutral	Non-Abstract Negative
3	1	1

Table 2: P1 - Number of Non-Abstract Sound Examples

Participant 1 did not feel that non-abstract sounds inherently contributed to a greater degree of player immersion in games. Instead, they felt that the style of sounds needed to match the style of the game. That is, a more realistic game should feature more realistic sounds, whereas a more conceptual or cartoon-aesthetic game should have more abstract sounds. In their opinion, it is the matching of sound styles to game environment that creates a greater sense of immersion.

4.4.2 *Participant 2*

The second participant felt that the difference between abstract and realistic sounds was not unlike the difference between diegetic and non-diegetic sounds. To them, an abstract sound was not only something that was not directly in the scene, but also something that was not natural, expected, or necessary to portray something realistic within the aesthetic of the game. Non abstract sound they felt was much easier to define, simply being something that was in the scene and that they could identify as making an expected noise.

Most of the examples that were given for abstract sound effects were different kinds of earcons typically used when a player interacts with the game's user interface. They also noted, however, that a disembodied tutorial voice would also be an example of an abstract sound, on the condition that the voice was not coming from a character within the game as justified by the presence of some sort of communication device. Much like their abstract examples, many of their realistic examples were also of neutral events. Participant 2 mainly focused on realistic environmental sounds, such as the sounds of footsteps or people in the game talking, when discussing realistic game audio.

Abstract Positive	Abstract Neutral	Abstract Negative
1	5	0

Table 3: P2 - Number of Abstract Sound Examples

When asked about immersion, Participant 2 stated that realistic sounds would only contribute to it in the case that the game is also realistic. Like the first par-

Non-Abstract Positive	Non-Abstract Neutral	Non-Abstract Negative
2	7	2

Table 4: P2 - Number of Non-Abstract Sound Examples

ticipant, they believe that the kinds of sounds that contribute to immersion are highly dependent on context.

4.4.3 *Participant 3*

The third participant had a much different view on what made a sound abstract or realistic. They looked at the questions from a music-based standpoint, and after some deliberation, decided that abstract sound was more about adding "texture" to the world. They explained that this was accomplished by creating musical elements using non-instruments, like tiptoeing sounds. The source of these sounds often cannot be seen, and the sounds in general are not as "in tune" with the environment. Non-abstract sounds, on the other hand, were defined as much more literal; a sound that makes sense for the environment that both originates from the game world, as well as being something that can be seen. Additionally, they mentioned that there was an element of expectation, citing music tracks that would be playing that the player does not question or isn't confused by the source of.

Preferring to speak in generalities, Participant 3 did not cite many specific examples compared to other respondents. Most of those provided were of neutral and abstract sounds, although one example of realistic sound was given for each coded category: positive, neutral, and negative.

Abstract Positive	Abstract Neutral	Abstract Negative
1	3	0

Table 5: P3 - Number of Abstract Sound Examples

Non-Abstract Positive	Non-Abstract Neutral	Non-Abstract Negative
1	1	1

Table 6: P3 - Number of Non-Abstract Sound Examples

Participant 3 felt that the use of realistic sounds contributed to a player's sense of immersion, stating:

> *"I think non-abstract sound is very well honed to creating that immersion. I think it's more about removing those kind of game-y constructs that reinforce that you're playing and that you maybe are not necessarily in [the game's] environment."*
>
> *-P3*

4.4.4 *Participant 4*

The fourth participant echoed many previous opinions on how to define the different types of sound. They described abstract sound as having no real source, being not realistic, and feeling alarming or out of place. Non-abstract sounds were described as having a source within the game world, being realistic and part of the environment.

Of the examples that Participant 4 provided, no specific kind of game event was favoured over others. The participant seemed to prefer to give a broad range of examples, from neutral notification noises to earcons indicating an error or success. Similarly, non-abstract examples consisted of environmental sounds and realistic success noises, such as a locked door clicking as the player picks the lock.

Participant 4 felt that realistic sounds were some of the heaviest influences on player immersion in games. They related the experience of playing *The Elder Scrolls V: Skyrim* (Bethesda, 2011) both with and without sound, and discussing

Abstract Positive	Abstract Neutral	Abstract Negative
1	1	1

Table 7: P4 - Number of Abstract Sound Examples

Non-Abstract Positive	Non-Abstract Neutral	Non-Abstract Negative
0	2	1

Table 8: P4 - Number of Non-Abstract Sound Examples

how much of a deeper experience the game provided with the audio on (having previously explained that many of the sounds in *Skyrim* are realistic).

4.4.5 *Participant 5*

Participant 5 also offered somewhat similar insights to those mentioned previously. They explained that abstract sounds were constructed or synthesized sounds that do not have any relation to what events are occurring in the game. Non-abstract sounds, on the other hand, believably map actions within the game to sounds that players would expect those actions to make in real life. To that end, they claimed that realistic sounds were almost entirely centered around things that are "real" within the game world. They also elaborated on the role of a player's expectation in this type of audio, saying that in general, people are able to determine if, although something is not real, it sounds "right" to them.

When providing examples of each type of sound, Participant 5 focused on earcons representing positive and neutral game events when discussing abstract sound. For realistic sounds, they focused on environmental sound effects, much like many other participants.

When asked about immersion, the fifth participant felt that realistic sounds definitely contributed to the amount of immersion in a game, saying:

Abstract Positive	Abstract Neutral	Abstract Negative
4	3	0

Table 9: P5 - Number of Abstract Sound Examples

Non-Abstract Positive	Non-Abstract Neutral	Non-Abstract Negative
0	5	0

Table 10: P5 - Number of Non-Abstract Sound Examples

> *"Yeah, absolutely, I think that it can be among the single most important aspects of a game's immersion factor is how well they create an audio landscape, as they like to call it, where you have a believable sound environment..."*
>
> *-P5*

They went on to describe how many games that have not aged well visually still have believable and immersive sound environments.

4.5 DISCUSSION

Examining the responses of all participants, many common threads arise. Most of the participants indicated that there was some element of diegesis that separates abstract and realistic game sounds. Although this is a compelling notion, each respondent also felt that there was more to these kinds of sounds than simply whether the characters in the game could hear them as well. Some participants discussed the role of player expectation in determining whether a sound is abstract or not, including both the player's expectation that an action should make a noise, as well as whether the action makes a noise that the player expects it to make.

None of the answers given held any indication that one type of sound was exclusive to one kind of game event. Of 51 example sounds provided (24 abstract, 27 realistic), the majority were of game events that could be considered neutral (16 abstract, 16 realistic). While the number of positive events for both abstract and realistic sounds were similar (7 abstract, 6 realistic), there was a difference in examples provided for negative events (1 abstract, 5 non). Almost all of these negative events were related to the player character taking damage, with only one relating to the encumbrance of the character. This may indicate that players prefer to hear or more readily associate events occurring to their character to more realistic sounds. This notion is contradictory to the interview results in Study 1 (see Section 3.5.4), in which respondents were evenly split on whether they would prefer an abstract or realistic sound to alert them of critical levels of health.

Additionally, no answers given indicated that either abstract or realistic sounds were exclusive to a single categorization or type of sound beyond their level of diegesis. Of the examples given, it is possible to argue that both realistic and abstract sounds can be adaptive, interactive, or dynamic as per the definitions proposed by Collins [13].

Based on the information gathered, it is possible to begin to define the contributing factors to abstraction within game sounds (Figure 11).

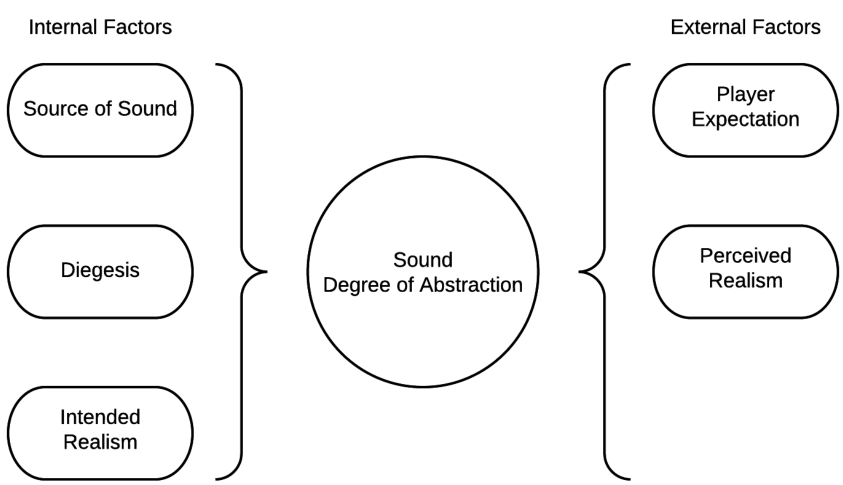


Figure 11: Anatomy of Sound Abstraction

As described in the interview results, there are several factors that cause a sound to be abstract or realistic. Furthermore, game and sound designers have varying degrees of control over these factors. Internally, designers can decide upon the degrees of realism, diegesis, and source of the sound. To create non-abstract sounds, designers should strive to develop realistic and diegetic sounds with a tangible source in the game world. Abstract sounds are conversely characterized by lower degrees of realism, as well as low levels of diegesis and without tangible sources within the game world. However, despite designing for these things, there are also external factors at play and the player ultimately determines whether a sound is truly abstract or not. Different players can have varying expectations or experiences that dictate how they believe an action or response should sound. This can also relate closely to how realistic they perceive a sound as being. Although interview respondents did not comment much on this specifically, many of them mentioned that the expectations of the player had a large part in whether they would categorize a sound as abstract or realistic. This follows the findings of McGregor [42], who has shown that it is worthwhile to compare the listening experiences of both sound designers and non-experts. In this case, players may perceive a sound in a slightly different manner than the designers had originally intended.

At the present time, Figure 11 should be considered incomplete, as this has only been an introductory study into these classifications of sound. It can, however, be seen as a starting point for future research in the area of video game sound design, and should be studied more closely especially with respect to existing work in sound classification, such as those by Collins [13] and Jørgensen [31].

4.5.1 *Validity Limitations*

The internal validity of this study is primarily limited by the small sample size. Initially, this series of interviews was merely intended to ensure that there was some agreement on what constituted abstract and realistic sounds in games. To obtain a greater understanding regarding the intricacies of these classifications of game sound, a follow-up study should be conducted, including both interview and gameplay components. This study, however, provides a basis for further research, and accomplished its original goal of providing a basis for the experimental study covered in Chapter 5.

Furthermore, it is possible that the external validity is limited by participant selection. The sample chosen is not representative of the typical video game player. As the intention of the interview was to obtain insight from developers, those who merely played video games were excluded from the study. This distinction was primarily made to get a more accurate picture of the definitions we were looking for from a North American industry standpoint. In the future, experiments looking to determine the effects of these types of sounds on the player experience will require a more globally representative population. Furthermore, there may be cultural differences that cause the characterizations of each type of sound to vary slightly depending on the region, supporting this need for a more global population.

4.6 conclusion

In this study, we have developed a rudimentary understanding of what professionals in game design and game audio feel defines *abstract* and *realistic* audio within video games. Using this information, an initial understanding of what factors contribute to the classification of these kinds of sounds has been determined. It was found that *abstract* audio is synthetic, non-diegetic audio that doesn't carry an inherent meaning or represent something physical within the game world. Conversely, *realistic* audio is often diegetic and fits the player's expectations of what an object or action is supposed to sound like in the real world.

Primarily, the goal of this study has been to provide a platform for future research, both for the remainder of this thesis as well as in the academic community in general. With what we have learned, it is possible to continue examining both the taxonomy of abstract and realistic game sounds as well as their effects on the player experience. These future works could lead to a more in depth knowledge of how to effectively design and use different kinds of sounds in commercial video games.

Detailed in the following chapter is one such study seeing to examine the effects on player performance and experience of each type of audio. Moving forward, the results obtained here should be used to frame other experiments designed to study informative game audio.

4.7 future work

Although all participants were consistent in their general definitions of *abstract* and *realistic* game sounds, it would be useful to do a follow up study with a larger participant base to verify the classifications that were discovered, as well as to determine any other nuances of each category. It would also be worthwhile to examine more closely the terms defined by Collins [13] to understand the relationship, if any, between adaptive, interactive, and dynamic audio as well as their subcategories and the notions of abstract and realistic audio.

In further work, the effects of abstract and realistic audio on the play experience should be more closely examined. A greater understanding of how the type of audio presented affects the player's reactions could be valuable to game audio designers, as well as other researchers in the area of informative game sound. In the following chapter, a controlled experiment is performed to investigate whether players perceive abstract or realistic audio as more preferable or more useful in two of the sound design patterns identified by Ng and Nesbitt [53].

4.8 summary

This chapter has detailed a short qualitative interview study involving five participants with either game development or sound design backgrounds. Each interview lasted approximately 35 minutes and primarily involved having participants define and provide examples of *abstract* and *realistic* sounds in video games. From this, a basic understanding of how these sounds are categorized and used in games was gained. Upon examining the results, it was found that the level of abstraction of a game sound is dependent not only on the sound designers, but also on the player's prior experience and expectations. Figure 11 was developed to show the interplay of the identified factors.

Using this information, the sounds used in the study described in the following chapter were chosen.

5 STUDY 3: IMPACT OF ABSTRACT AND NON ABSTRACT SOUNDS

5.1 INTRODUCTION

In the final experiment, the effects of *abstract* and *realistic* feedback audio were explored. The intention was to gain a basic understanding of both the effectiveness of each type of audio for performing tasks within games, as well as if there is any experiential difference between the two, including any differences in the thoughts or feelings of players as brought on by the different types of sound. To get a more complete picture, it was necessary to run more than a single experiment. Ideally, each design pattern of informative game audio would be tested, however because of the overhead of creating many experimental games, two were chosen. Environmental awareness and perception of character health were measured. These were chosen primarily because of the frequency with which players of commercial FPS games need to perform these tasks, but also because of health sounds being examined in the first study, too.

To measure each type of audio for each task as controlled as possible, it was necessary to develop two different applications. Using the game from experiment 1 (Section 3.3), the environment and objectives were tweaked so that the only actions required of the player were related to gathering information from these sounds. In addition to measuring the performance of the tasks, the players provided an assessment of their mental state and answered semi-structured interview questions regarding their reactions to each relevant sound.

5.2 RELATED WORK AND MOTIVATION

The study detailed in this chapter was motivated primarily by the results of studies 1 and 2. Particularly, the interview results from Study 1 suggested that players did not have a clear preference of whether abstract or realistic feedback audio should be used to inform them of changes in their character's health. Study 2 was conducted as an interim between the first study and this one, to ensure that the properties of each type of sound were properly understood.

As discussed in Section 3.6, no significant effects relating to the physiological state of participants were observed in the previous experiment. Despite physiological measures being useful in identifying a greater amount of issues within games than traditional methods alone [45], this confirms previous results by Nacke et al. [52] in which no physiological effects were experienced as a result of game sound. Therefore, the decision was made to exclude physiological measures from this study.

We decided to adopt a much more directed approach to obtaining results in this study. Game data was once again logged, and player affect was measured using the SAM questionnaire [9] to give insights into player emotions. The qualitative data from the interviews in the previous studies was helpful and, thus, we additionally decided to use interviews in this study, too.

Once again, the work done by Ng and Nesbitt [53] was consulted to choose which sound design patterns to focus on evaluating. These, along with the player-health-related data gathered in Chapter 3 offered a point to begin examining the functional aspects of abstract and realistic audio in games. Until this point, no practical work had been done in examining the differences between the effects that abstract and realistic informative feedback had on either player experience or performance in games. In the following study, it is sought to determine if either type of sound has significant benefits over the other when being used for the purposes of perception of character health or awareness of changes in the in-game environment.

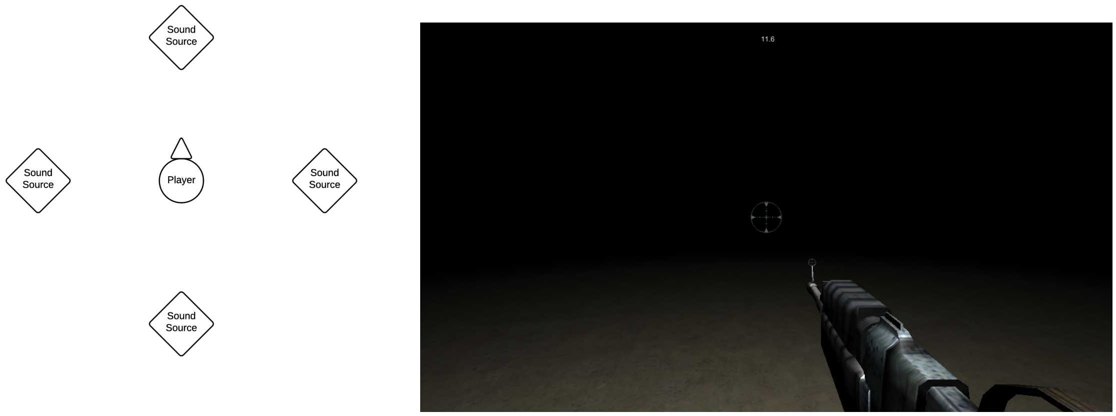
5.3 THE GAME

5.3.1 *Overview*

To examine the effects of abstract and realistic game sound, two separate game-based tasks were developed, using the game framework of study 1 (see Section 3.3). Each version was centred around a basic task that falls under one of the sound design patterns outlined by Ng and Nesbitt [53]. The patterns selected were *impending death* and *environmental awareness*. Both versions were stripped of gameplay and focused entirely on the task related to reacting to the sound. The player character is placed in a dark room, only able to see a short distance in front of them. A player can only change the direction the character is facing, and interact with the task using a single button.

In the environmental awareness task, a participant hears a sound coming from one of four random locations surrounding them, and must locate the source of the sound as quickly and accurately as possible. The sound will loop until the player presses the button to confirm where they think it is located, then another sound begins to play after a brief period of silence. Each possible sound source will play twice, for a total of eight sounds to locate.

In the impending death task, the player character takes a randomized amount of damage at an irregular interval. The participant is asked to press the button when they feel that they have 25% of their health remaining. When the player takes damage, there is a brief red flash, accompanied by a grunting sound. After the first hit occurs, an abstract or realistic sound will play intermittently, linearly increasing in frequency for every 15% of health that is lost. Once a participant presses the button to indicate that they feel they are near 25% health, a bar ap-



(a) Study 3 phase 1 sketch

(b) Study 3 in-game experiment view

Figure 12: Study 3

pears, showing the exact level of health that their character had. In the event that a participant allows their health to fall to zero, the game exits automatically and the trial is considered a failure.

5.3.2 *Audio and Other Feedback*

In the first phase of the experiment, the only pieces of feedback provided to the player are: a looping spatial sound emanating from one of four sources, and a timer featured at the top of the screen, showing participants the number of seconds that have elapsed since the sound began. The sounds that were chosen were a beeping tone, as representative of abstract sounds, and footsteps, as representative of realistic sounds. In investigating the pattern of environmental awareness-based audio, the beeping noise is unexpected and not tied to a definitive source within the game world, and the footstep sounds are comparatively more suited to the environment, and make sense within the context of the world, even if their source is not visible. No other feedback was provided to participants.

In the second phase, a participant hears a grunting noise and the edges of the screen flash with a blood texture when any damage is received. Additionally, a health warning noise begins sounding as soon as they are hit for the first time. This noise starts out intermittent, and grows more frequent with every 15 health points that the character loses. In the abstract sound condition, the health warning noise is a simple warning beep, as used in study 1, whereas the sound used for the realistic condition is a beating heart.

5.3.3 *Game Metric Data*

In the first phase of the experiment, the game collects two main data points:

- *Time to Target*: The time it takes a participant to locate the source of the sound. The time is recorded as the number of seconds from when the sound began emitting until the confirmation button is pressed.
- *Accuracy*: The angle between the participant's targeting reticle and the centre of the sound source, in degrees. As the minimum angle is 0 (crosshairs are positioned exactly on the sound source) and the maximum is 180 (crosshairs are positioned exactly opposite from the sound source), it is possible to calculate a percentage that is representative of how accurate a participant's location guess is.

The position of the player character and the direction it is facing is also stored, along with the computer's system time and the total time elapsed since the game was started. These additional data points are not directly related to the outcome of the experiment, and are only present in the event that there is a need to verify the primary data gathered.

In the second phase of the experiment, only one main piece of data is collected:

- *Amount of Health Remaining*: The amount of health that the participant's character has remaining as of the time that they press the confirmation button. This number will be between 0 (no health remaining; a failed attempt) and 100 (the maximum level of health).

As in phase 1, additional positional, directional, and time data is gathered, but was not used for in-depth analysis.

5.4 METHOD

5.4.1 *Experimental Design*

For this study, I used a modified version of the game developed for Study 1 (see Chapter 3). All of the gameplay elements were removed, including both objectives and enemies, and the game was reduced to the completion of a single experimental task. Two such builds of the game were created, each focusing on a different task. One version was concerned with measuring the effect of abstract and realistic audio feedback on a participant's in-game environmental awareness, while the other focused on impending death and the participant's ability to judge their level of health based solely on the different types of audio.

It was important that the experience of each type of audio was recorded for each participant, so a within-participants design was used. The experiment itself was ran in two phases: completing the environmental awareness task, and then completing the impending death task. The player experience was evaluated for changes in the type of audio; that is, abstract audio or realistic audio, for each task. Each phase was counterbalanced to account for any possible learning effects. That is to say, all participants completed the environmental awareness phase before completing the impending death phase, but experimental conditions within each phase were counterbalanced. The sounds used for each phase were different, because of the difference in nature of the tasks, and as such, it is unlikely that there were any learning effects from phase 1 that could have affected phase 2. For more information, please see Section 5.4.5 and Figure 13.

Participants were instructed to play each task until it was completed, and each condition was followed by a SAM questionnaire [9]. Furthermore, after each phase of the experiment, a short interview was recorded with participants to obtain a more thorough understanding of their feelings towards each type of sound and their play experience in general.

5.4.2 *Participants*

A total of 30 people (14 female) participated in the experiment, ranging in age from 18 to 34 years ($M = 23.73, SD = 3.80$). No data from any participants was excluded for any reason, therefore all collected data was usable.

Effort was taken to recruit both participants that were experienced video game players as well as those that were novices or new to the medium (On a 7-point Likert scale on which 1 is inexperienced and 7 is experienced, $M = 4.80, SD = 1.90$), with players spending between 0 and 84 hours per week playing games ($M = 10.02, SD = 17.18$). On average, all participants had moderate experience with FPS games ($M = 4.17, SD = 2.31$ on the previous Likert scale).

To ensure that participants would provide usable data for the study, an optional demographic question was included asking participants if they had any impairments to their hearing. Only one participant answered 'yes', with one other preferring not to give an answer. Both of these participants were able to complete all tasks related to the experiment without difficulty and as such their data was not discarded.

5.4.3 *Experimental Environment*

The experiment was performed at the Game Science Lab at UOIT. Participants were seated at a desk with a workstation that had all files required to run the game. They were also provided with a pair of high quality headphones and an XBox 360 controller for input. No additional materials were required of the participant, and the experiment was limited to a single lab session. The experimenter was present at all times during the study, although they were seated out of view of the participant so as not to distract them.

5.4.4 *Data Management*

All identifying participant data was anonymized for the experiment. After signing the consent form, each participant received an identifier that they are referred to as in each piece of information collected. No information that could lead to a participant being identified was stored.

The game metric data was collected on the computer that each participant used to run the games. After each play session concluded, a log file of relevant data was created on an external hard drive that was stored in a locked cabinet in the UOIT GAMERLab.

Questionnaire results were collected on paper, and digitized after the session had concluded. The digital copies were stored on the aforementioned hard drive, while the paper copies were stored in a locked filing cabinet in the UOIT GAMERLab.

Interview responses were collected and recorded in the same manner as Chapter 3; each interview was recorded using a mobile device and was synced to the private account of the experimenter. These interviews were transcribed by an undergraduate research assistant who was not present for the experimental sessions and therefore could not identify the participants. Following transcription, the results were analyzed by both the primary experimenter and one other research assistant not previously involved with the experiment.

5.4.5 *Procedure*

Participants were welcomed to the lab and briefed upon the experimental process. After signing a consent form, each participant filled out a short demographic survey (see Section A.8) regarding their gameplay habits. Afterwards, the first task was explained and the first condition of the first experimental phase was completed. Participants were then instructed to fill out a SAM (see Section A.4) to indicate their play experience. The second condition was then completed, followed by another SAM questionnaire. Upon completion of the first phase, a short interview was recorded with the participant (see Section B.3).

Phase 2 was conducted in a similar way to the first. The task was explained to participants, and the first condition was administered. Once again, a SAM questionnaire was filled out. The final experimental condition was then completed, and a final SAM was collected. Finally, the interview for the second phase of the experiment (see Section B.4) was recorded, and participants were debriefed and thanked for their participation.

5.5 results

The experimental results are recorded below, separated into different categories signifying the kinds of data collected. First, the survey results of the SAM are covered. Next, task performance data is discussed, followed finally by the findings from the interviews. Within each category, data has been further sectioned into that which is relevant to the environmental awareness task, and that which is relevant to the perception of health task.

All measures that have satisfied parametric assumptions have been evaluated using a paired samples t-test, and those that do not satisfy parametric assumptions have been evaluated using a Wilcoxon signed-ranks test.

5.5.1 *Survey Data*

Below are the SAM results for both phases of the study. The questionnaire was scored using a 9-point Likert scale. On the valence subscale, a lower score indicates a more positive valence while a higher score indicates a negative one.

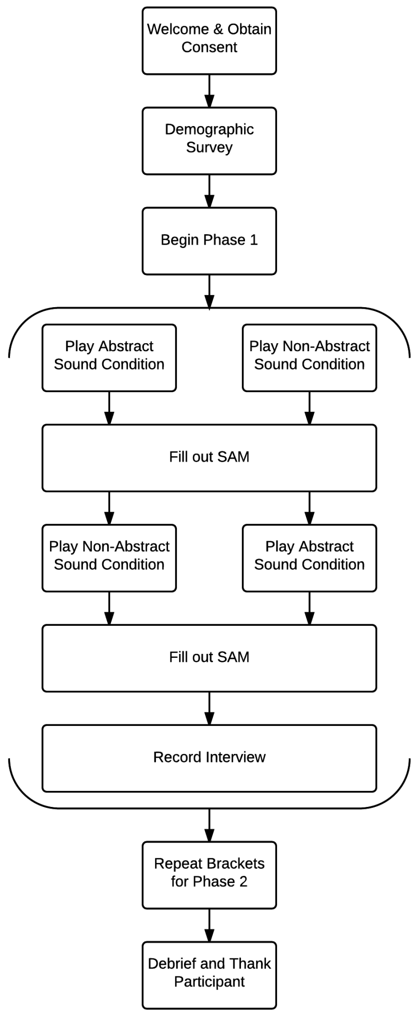


Figure 13: Study 3 Procedure

Similarly, lower scores on the arousal scale indicate higher levels of arousal while higher ones indicate lower arousal. Finally, low dominance scores are indicative of low levels of dominance, and high scores indicate higher levels of dominance. For more information, see Section A.4.

5.5.1.1 *Environmental Awareness*

None of the survey results in the environmental awareness phase were normally distributed. Participants experienced similar levels of pleasure when playing with abstract ($M_{Abs} = 3.93, SD_{Abs} = 1.596$) and realistic ($M_{Non} = 4.07, SD_{Non} = 1.617$) sounds. Likewise, there was little difference observed between the levels

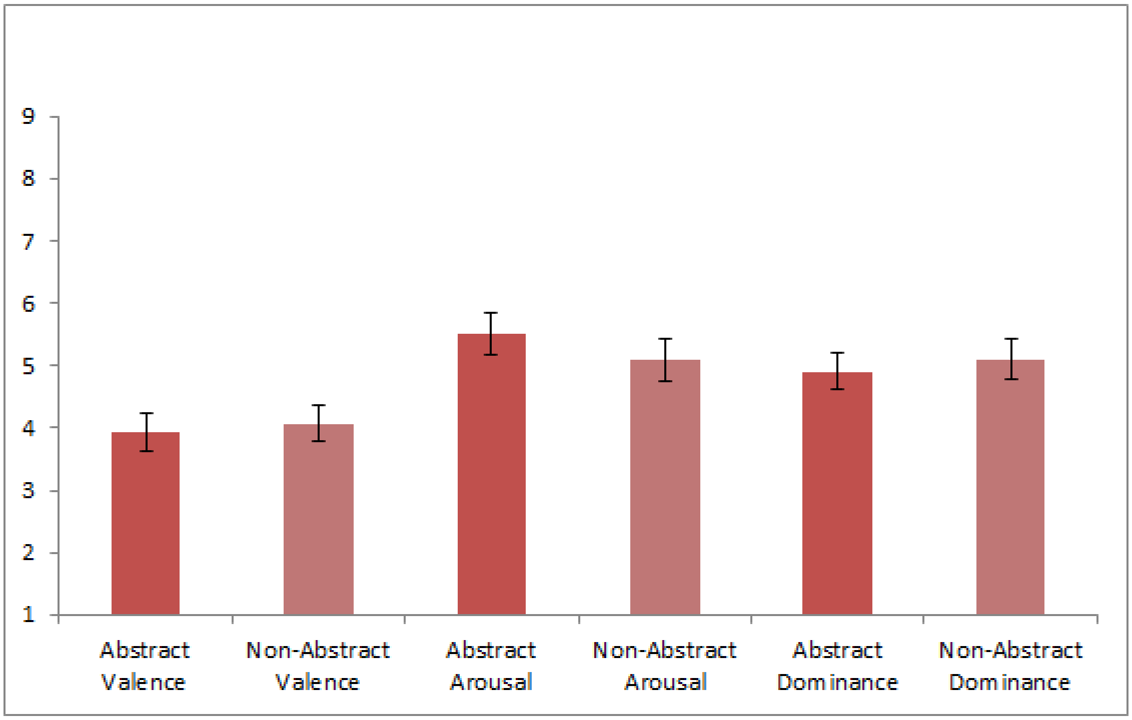


Figure 14: Study 3 Environmental Awareness SAM Means

of dominance reported across abstract ($M_{Abs} = 4.90, SD_{Abs} = 1.561$) and realistic ($M_{Non} = 5.10, SD_{Non} = 1.807$) conditions. Participants appeared to experience slightly higher levels of arousal when playing with abstract sound ($M_{Abs} = 5.50, SD_{Abs} = 1.834$) than with realistic sound ($M_{Non} = 5.10, SD_{Non} = 1.845$), but this difference was not significant.

5.5.1.2 *Damage and Impending Death*

In the health perception phase of the experiment, only the results for the pleasure scale of the SAM satisfied parametric assumptions. There was, however, no significant difference between the pleasure reported by participants as a result of abstract ($M_{Abs} = 4.43, SD_{Abs} = 1.906$) or realistic ($M_{Non} = 4.23, SD_{Non} = 1.942$) feedback audio. There was also not a noticeable difference between the reported arousal when playing with abstract ($M_{Abs} = 4.67, SD_{Abs} = 1.516$) or realistic ($M_{Non} = 4.37, SD_{Non} = 1.326$) sound. Finally, participants experienced similar

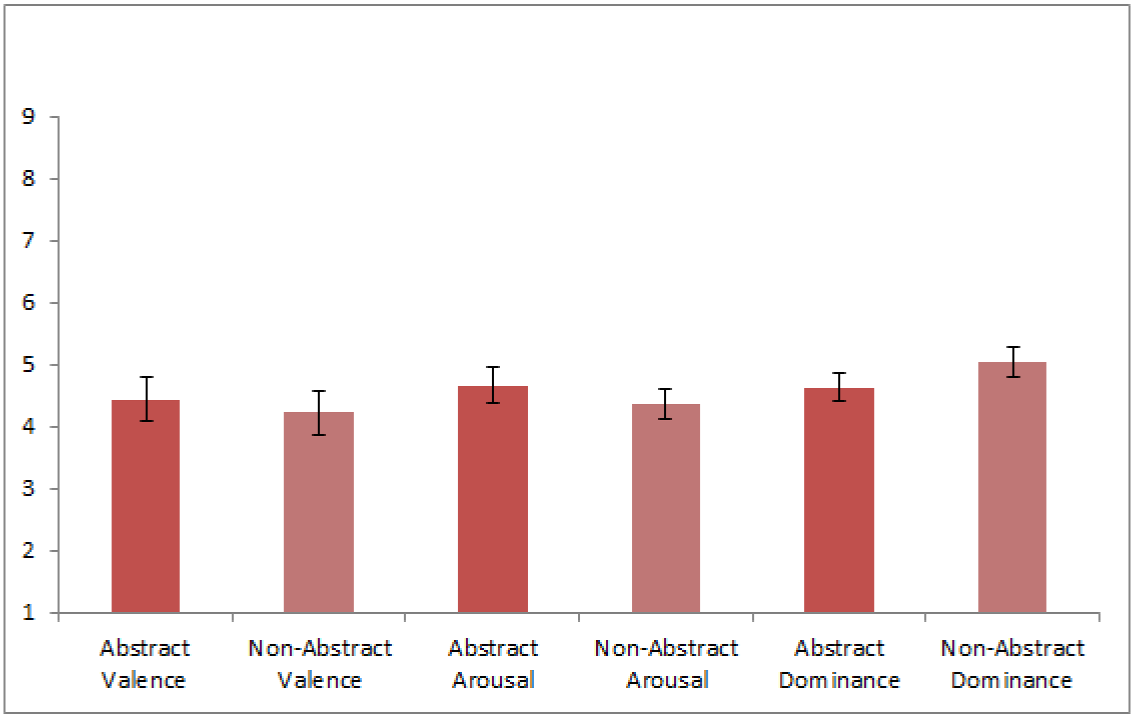


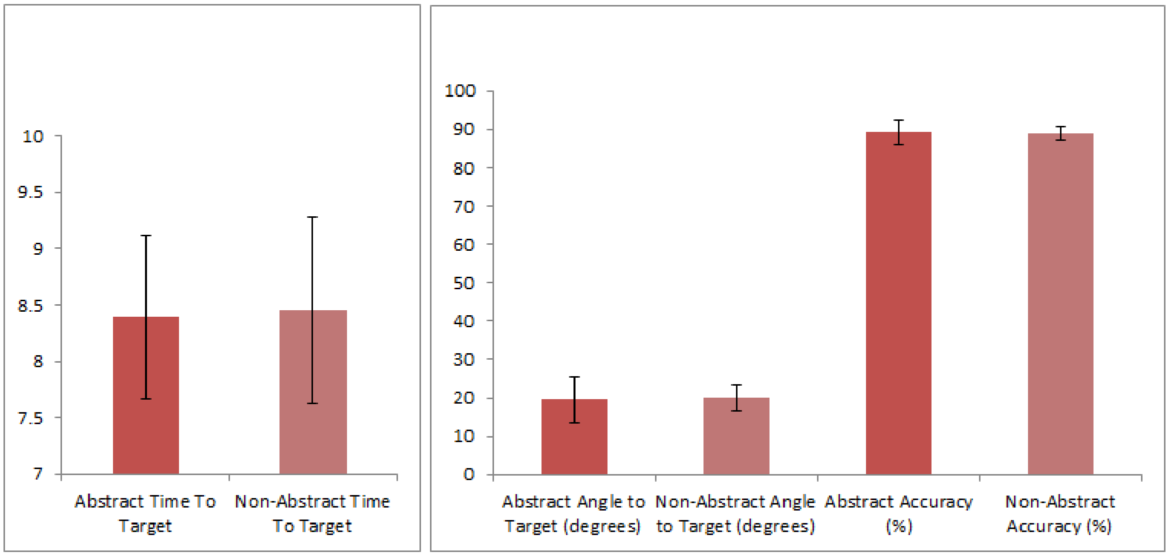
Figure 15: Study 3 Health Perception SAM Means

feelings of dominance whether the sound was abstract ($M_{Abs} = 4.63, SD_{Abs} = 1.273$) or not ($M_{Non} = 5.03, SD_{Non} = 1.377$).

5.5.2 *Game Performance Data*

5.5.2.1 *Environmental Awareness*

The performance indicators during the first phase of the experiment were the speed at which a participant was able to locate a sound, as well as the accuracy of their guess. Time was measured in seconds, and the accuracy was measured as the angle between the direction the character was facing, and a vector drawn from the player's position to the source of the sound. This angle was then converted into a percentage value, assuming 0% accuracy at an angle of 180 degrees (i.e. the player is facing the direction exactly opposite the sound) and 100% accuracy at an angle of 0 degrees (i.e. the player is facing the source of the sound exactly).



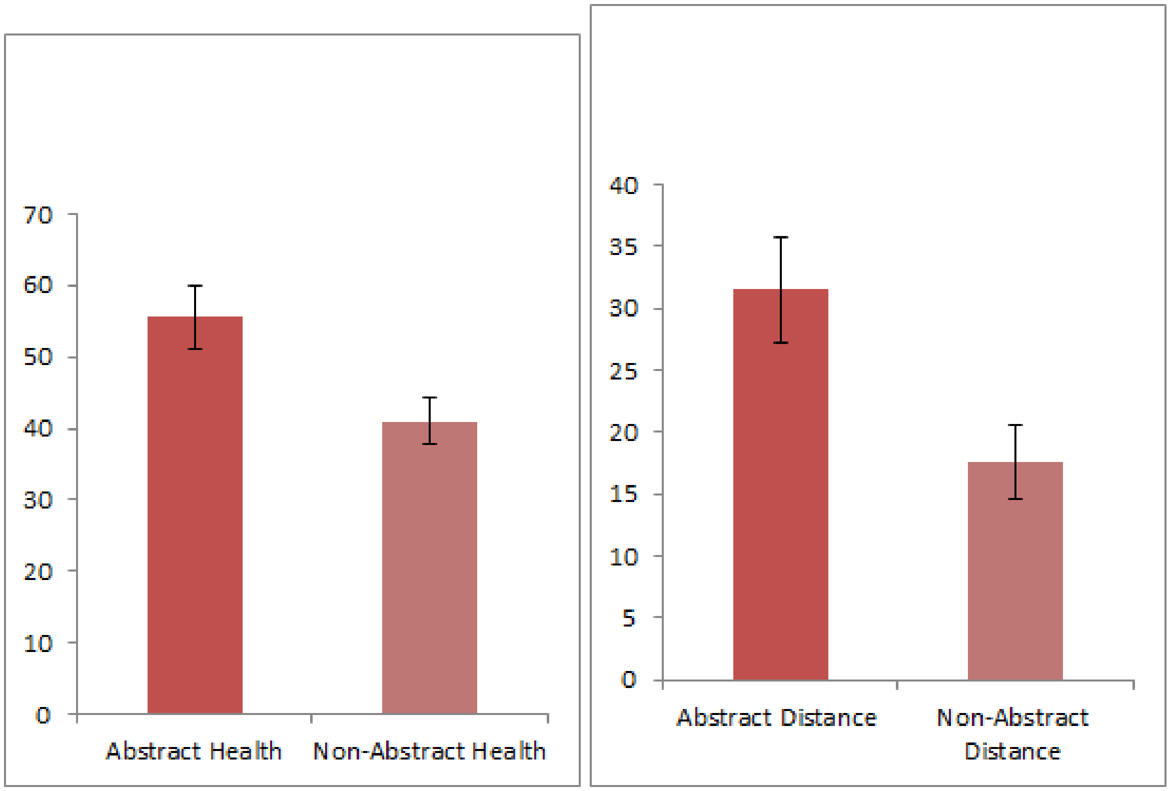
(a) Time taken to select target

(b) Accuracy

Figure 16: Study 3 Environmental Awareness Performance Measures

The data for time was normally distributed, while both measures of accuracy were not. Participants were extremely accurate in both the abstract ($M_{Abs} = 19.60 degrees, SD_{Abs} = 32.52 | M_{Abs} = 89.11\%, SD_{Abs} = 18.07$) and realistic conditions ($M_{Non} = 20.09 degees, SD_{Non} = 18.94 | M_{Non} = 88.84\%, SD_{Non} = 10.52$) conditions. Likewise, the average times taken to confirm the location of a sound were similar regardless of whether the located sound was abstract ($M_{Abs} = 8.39s, SD_{Abs} = 3.99$) or realistic ($M_{Non} = 8.45s, SD_{Non} = 4.50$).

Although in many cases the differences are not large, when looking at the results across all participants, 14 (47%) people completed the realistic task more quickly, while 16 (53%) were able to complete the abstract task more quickly. In terms of accuracy, 10 (33%) participants were better at locating realistic sounds compared to abstract sounds, while 20 (67%) performed better when listening for abstract sounds.



(a) Health remaining (b) Difference between remaining and target

Figure 17: Study 3 Environmental Awareness Performance Measures

5.5.2.2 *Damage and Impending Death*

The performance indicators for the health perception task were the amount of health that the character had remaining, as well as the absolute difference between that value and the target value of 25.

Neither of the metrics were normally distributed. However, participants seemed to estimate their health was much lower when hearing abstract feedback ($M_{Abs} = 55.57, SD_{Abs} = 24.562$) than with realistic feedback ($M_{Non} = 41.00, SD_{Non} = 18.137$), $z = -3.018, p = 0.003, r = -0.551$. It therefore follows that the absolute distance from the target health was much higher in the abstract condition ($M_{Abs} = 31.50, SD_{Abs} = 23.310$) than that in the realistic condition ($M_{Non} = 17.60, SD_{Non} = 16.533$), $z = -2.791, p = 0.005, r = -0.510$.

When examining which experimental conditions were the most successful for each participant, it was found that 19 (63%) players had the most accurate estimate of their health when listening to the heartbeat sound. There was a single participant (3%) that managed to have the exact same distance from the target health in both conditions, while the remaining 10 (33%) experienced greater success with the beeping alert.

5.5.3 *Interview Data*

The results of the interviews for each phase of the experiment are detailed below. Participants were asked questions regarding their preference of the two sounds, as well as to evaluate how well they thought that they performed each task. For a full list of questions, see Section B.3 and Section B.4.

5.5.3.1 *Environmental Awareness*

When asked which of the two sounds they preferred, 21 (70%) of participants liked the realistic footstep sound better. However, when asked which sound they felt was more useful, 14 (47%) participants felt that the abstract alert sound was better suited to the task. Another 14 (47%) felt that the footsteps were more useful, with the remaining 2 (7%) claiming that both types of sounds had their useful aspects, and that neither was more suited to the task than the other.

Most participants (22, 73%) felt that they could accurately identify the source of the sound, while another 5 (17%) were unsure, with 3 (10%) that felt that they could not find the sounds at all. Players were more confident in their ability to find their targets quickly, with 25 (83%) claiming that they had no trouble doing so. Another 2 (7%) were less sure of themselves, with the remaining 3 (10%) reporting that they had difficulty completing the task in a reasonable amount of time.

Participants were also asked if they had any additional comments regarding either sound. Most did not have anything helpful or informative to say, although several mentioned that the footsteps (realistic) sounded more natural to them. A few participants (3, 10%) remarked that the sound of the footsteps was creepy and made them anxious. Other than that, a few participants remarked on different properties of the sounds, with one claiming that the footsteps sounded as if they were moving around the room and were thus harder to locate. Another participant claimed that it was more difficult to tell if the footsteps were in front of, or behind the character than when listening to the abstract beeping. Little was said about the abstract noise, with one participant describing it as a negative noise, like an alarm.

It is worth noting that no participants had anything objectively negative to say about either type of sound, regardless of their preference or past gaming experiences.

5.5.3.2 *Damage and Impending Death*

As in phase 1, participants were first asked about their preference of sound. Most (22, 73%) preferred the realistic heartbeat sound, while 5 (17%) preferred the abstract beeping. The remaining 3 (10%) participants did not have a clear preference for one type of sounds over the other. Interestingly, when asked which type of sound was more useful for estimating remaining health, only 18 (60%) felt that the realistic feedback was better suited to the task. Another 9 (30%) felt that the beeping sound was a better indicator, with 3 (10%) holding no preference.

Responses were mixed in terms of being able to accurately determine how much health the character had remaining. Only 12 (40%) participants felt that they were reasonably able to estimate how much health they had remaining, while 10 (33%) had almost no idea. The remaining 8 (27%) expressed having a vague idea of what their level of health was, but had little confidence in their assumptions.

Much like phase 1, many participants mentioned in some way that the realistic sound was more natural for the situation. Some reported being familiar with it as a measure of health, while others simply mentioned that it made the exercise feel more urgent, or more personal. Furthermore, two participants explicitly stated that the heartbeat made the task more immersive. With regards to the abstract beeping notification, two participants felt that it was out of place, while another claimed that it made them feel anxious. A single participant even mentioned that the beeping annoyed them. Finally, one other participant mentioned that performing the task using only sounds was strange and unnatural, citing that games often provide a health bar to consult for a more accurate reading of health.

5.6 DISCUSSION

The lack of statistical significance for any of the quantitative measures in phase 1 is surprising, although promising for designers who have a preference for one type of sound over the other for environmental awareness. The lack of player preference one way or the other reflects the same result obtained in Study 1, reinforcing that game and sound designers can have creative control over the kinds of informative sounds they use without worrying about alienating a part of their player base. It is worth noting that this split between preference of abstract and realistic sounds is not simply in relation to what kinds of sounds players like to hear, but also what kinds of sounds players feel are useful, at least in terms of understanding events happening around them in the game world.

Although 67% of participants performed better at locating abstract sounds, the difference in accuracy was still very small (see Figure 16b). As both the beeping sound and the footsteps had similar amounts of uptime (i.e. how often each sound can be heard), this slight advantage may be related to previous experiences with notification-like sounds, and warrants further study.

With regards to the SAM questionnaires, the lack of significance may be partially because of the short time involved in completing experimental tasks. Many participants were able to complete a given task in either phase of the experiment within five minutes, which may not have been a long enough exposure to the sounds to evoke a distinct change in emotion or play experience. It is possible that with a longer experimental session, or perhaps some meaningful gameplay consequences to task successes or failures, that some kind of reaction could be observed.

Interestingly, many participants felt confident in their ability to complete tasks successfully regardless of their actual ability to do so. This may be a side effect of a lack of feedback in the game to tell players if they were performing well or not. For example, one participant, P19, felt confident in their ability to locate where the sounds were coming from. She cited having "mom ears" as the main contributing factor to her perceived success, but in reality she averaged 55.64% accuracy when listening for the beeping sound, and 57.41% accuracy when listening for the sound of footsteps. By not providing feedback to the players, it prevented any learning effects that may have arisen from determining the "correct" sounds, but it may also have impacted the possibility for a more thorough analysis of the play experience.

Many participants struggled with the health perception task. Some felt that the instructions were not clear enough, or did not understand that the feedback noise would increase in frequency. This may have resulted in some participants ending their first trial prior to having a low level of health simply because of a perception that the noise, especially the abstract beep, must mean something bad. On one hand, this gives an interesting outlook into the amount of urgency that players associate with these kinds of sounds. Although they performed poorly at the task, this may simply mean that the beeping conveys a greater sense of danger to players than the heartbeat. This could possibly be a previously learned response, as participants may have a natural association with high pitched beeping in the form of alerts or alarms. As the average level of health for abstract feedback was 55.57%, it can be deduced that an abstract tone repeating every three seconds (the frequency for 50-65% health used in phase 2) is enough to communicate to a player that they are near death. When listening to the heartbeat, the players waited on average until the next set of intervals, feeling that they had low health at 41%, or one heartbeat every two seconds.

Despite the split preference of sound type in the environmental awareness task, it is interesting to note that in the health perception task, a clear majority (73%) preferred the realistic sound option. Although this contradicts some of what was said in the interview results from Study 1 (see Section 3.5.4), it is actually in line with some of the responses from Study 2 (see Section 4.4), in which some participants stated that realistic sounds were well-suited to player-centric events. This makes sense, especially when considering what some respondents had to say about their preference; for example that the heartbeat noise is something that you more readily associate with health, so it is easier to understand the information that the sound tells you.

Another interesting link to Study 2 is that many interview respondents claimed that the realistic variants of each task felt more immersive. This echoes what the experts interviewed for Study 2 claimed, stating that realistic sounds contribute to a greater degree of player immersion provided that the sounds are in context and the game environment is at least somewhat realistic. That immersion was especially evident in the cases of the two participants that referred to the footstep sounds in phase 1 as "creepy."

The only metric that showed statistical significance in the entire study was the players' ability to judge their level of health depending only upon either abstract or realistic feedback audio. Based on the comments outline above and in the interviews, this is not entirely surprising. Still, this is an important result, as it gives weight to the conjecture in the previous studies and offers a basis for future work to gain a deeper understanding of informative audio feedback. Moving forward, it would be worthwhile to further test abstract and realistic audio cues for other player-centric game events, in addition to other sound design patterns as proposed by Ng and Nesbitt [53].

Based on the results obtained in this experiment, more design recommendations for informative audio in FPS games can be made.

5.6.1 *Towards Design Recommendations for Informative Game Audio*

As in study 3, these recommendations are still at an early stage and will require follow-up studies for confirmation. The previous design recommendations from Section 3.6.1 will not be restated here, but all considerations will be listed together in Chapter 6.

- *When designing audio for feedback directly related to the player's character, favour realistic sounds*. The reasoning for this is two-fold; not only did players have an easier time estimating their level of health, but they also reported that the heartbeat sound made the experience more immersive. This is an important finding, since often game developers will forego more immersive design options in favour of more usable ones. The results of this study show that no concessions need to be made in the area of player-related feedback.
- *Offer players a relatively safe environment to learn the meanings of abstract audio cues*. One thing that became evident from both the initial health perception tasks of participants, as well as some interviews, was that sometimes players had difficulty understanding what element of the sound they were listening for. In the study, this was done intentionally to obtain a raw, unbiased idea of how players perceived each type of sound. In a game, however, players may get frustrated if they do not understand what the informative feedback is trying to communicate to them. Much like when introducing game mechanics, designers need to ensure that a player is exposed to these sounds in context and in such a manner that they have enough time to process and learn what the sound means.

5.6.2 *Validity Limitations*

Some of the limitations of internal validity have been briefly touched on in the bulk of the previous section. It is possible that the experiential SAM results are skewed, because of the short amount of time that participants had to interact with each task. This could have been solved by extending the running time of the experiment and adding additional trials for the environmental awareness phase. The health perception task was deliberately limited to one trial per sound type to prevent players from learning the exact sound patterns and being able to guess their health correctly each time, invalidating those results. In fact, it is possible there are issues with the health perception task already, because many participants performed significantly better in the second condition. As mentioned in the experimental design (Section 5.4.1), condition orders were counterbalanced across participants to minimize these effects.

While the sample of participants exhibited a broader range of game experience than those in Study 1, they were all students attending summer courses at the UOIT campus. Thus, it is possible that the results obtained from the study are not as applicable to the general public as would be hoped. However, care was taken in recruiting participants with a wide variety of gaming backgrounds to mitigate this.

5.7 CONCLUSION

In this experiment, the effects of abstract and realistic audio on the player experience were measured in the context of informative feedback for environmental awareness and perception of health. Although no significant effects were discovered for the environmental awareness phase, participants were better at estimating their character's health when listening to a realistic indicator. Furthermore, when interviewed, the majority of participants claimed that the realistic sounds provided a more immersive experience in both phases. It is important to note that these results are currently only applicable to FPS games, and more work must be done to verify these findings in other genres of video games.

This study contributes additional sound design guidelines to those initially proposed in Study 1 (see Section 3.6.1). The results obtained are promising, and give way to future studies structured similarly, but involving different sound design patterns. These may confirm the suggestion that realistic sounds are more effective when used to communicate direct changes to the player character's status.

5.8 future work

There are many opportunities to build off of the results of this study in future academic research. First, running similar studies measuring any effects of abstract and realistic sound should be conducted for the remaining sound design patterns outlined by Ng and Nesbitt [53]. These would offer a more complete picture of the effects seen in this study and help to contextualize optimal uses for each type of sound.

It would also be helpful to perform a case study of recent commercial games, to catalogue any patterns in the way developers use these sounds in modern games. By discovering patterns in the industry, it will become easier to identify areas that could be improved through academic research.

Finally, both environmental awareness and health perception should be explored thoroughly within the context of informative sounds. More in-depth studies would offer opportunities to confirm the results obtained here, as well as gain a deeper understanding of what contexts elicit the most favourable reactions from players. It would be worth repeating this experiment in a real-time gameplay context, as having additional game elements to focus on may change the ability of players to accurately interpret the sounds. This would in turn make the results more relevant to commercial game development, because they would be obtained from a traditional gameplay scenario.

5.9 SUMMARY

The final of three studies was discussed in this chapter. There were 30 participants, who each participated in two phases of completing game-based tasks using informative audio. The first phase was related to environmental awareness, in which a participant must locate the source of a sound as quickly and accurately as possible. In the second phase, the character in the game took damage at random intervals, and participants were instructed to indicate when they felt the character had 25% of its health remaining. There was a significant effect of the type of sound being played on their ability to estimate the character's health. This, as well as interview results indicating that realistic sounds made the gameplay experience more immersive were translated into guidelines for the design of informative game audio.

Part III

DISCUSSION

6 DISCUSSION

In this chapter, the results of each study are synthesized, and final remarks are made regarding the thesis statement outlined in Chapter 1. First, the results of each study will be discussed in terms of contribution to academia. This section has been structured to reflect the contributions presented in Section 1.5.

6.1 UNDERSTANDING INFORMATIVE AUDIO IN VIDEO GAMES

Throughout this thesis, work has been conducted to deepen the understanding of video game audio. A taxonomy was developed in Chapter 4 to categorize *abstract* and *realistic* game sounds. In addition to the usefulness of this distinction in selecting sounds for Chapter 5, it also offers an area for future research in types of informative game audio.

As we learn more about different levels of abstraction in game sounds, we will be able to continue to flesh out sound design guidelines and provide a terminology that game designers and sound designers can use to effectively communicate when designing games.

The results obtained in this thesis show that there can be experiential differences between the types of audio used within different game contexts. Specifically, I have shown that using realistic audio to represent changes in a player's health offers a more immersive and informative alternative to using abstract indicators. This result provides weight to the idea that a more thorough knowledge of these types of sounds will be useful to the commercial game industry.

6.2 SOUND DESIGN GUIDELINES FOR INFORMATIVE GAME AUDIO

All 6 design guidelines created based on the results of Chapter 3 and Chapter 5 are restated below from their respective discussions for reference:

- *Provide players with a clear auditory indication that they are being damaged.*
- *Alert players of impending death between 25% and 35% health.*
- *Try to offload information to audio cues.*
- *Involve members of the sound team in early design sessions.*
- *When designing audio for feedback directly related to the player's character, favour realistic sounds.*
- *Offer players a relatively safe environment to learn the meanings of abstract audio cues.*

As discussed above, these results are important because of their potential value to the commercial games industry. These design guidelines can assist game audio professionals in creating more effective informative sounds for players. Many important elements of gameplay require the player to process some manner of information to make meaningful decisions in a game. These can range from the depletion of critical resources, such as health or ammunition, to being able to understand what is happening in the game world around the character. By optimizing the use of sound to convey these kinds of information, there may be less cognitive load on the player, allowing them to further enjoy the experience of gameplay, rather than waste time and effort trying to determine what a specific sound is communicating to them. Especially in FPS games, where many decisions need to be made in a fraction of a second, players will benefit from an increased quality in informative sound design.

6.3 GAME FRAMEWORK

The game software developed in *Unity 3D* for Study 1 was adapted and used throughout the thesis. It provides all of the basic conventions of an FPS game, but also affords the ability to log any desired gameplay data. Using the framework as a base, it was simple to develop the game-based task scenarios for Study 3. The game was created in such a way that changing different pieces of audio was quick and easy to do, allowing for rapid development of future testing scenarios.

The game itself is a worthwhile contribution as it allows for the rapid testing and analysis of the absence or presence of different kinds of sounds within a real-time gameplay context. It has been shown in this thesis to be easily adaptable to isolating variables based on specific game-based tasks as well. This, combined with the ability to output any variables of interest to an easily readable log file make it a valuable tool for research relating to audio in FPS games.

Improvements needed to make the software extensible and therefore usable for other projects in other genres are detailed in Section 6.6.

6.4 GENERALIZABILITY

All of the experimental research within this thesis was conducted in the scope of FPS games. Therefore, the specific conclusions drawn here are only concretely applicable to the design and implementation of an FPS. The results suggest that some effects may be consistent in other genres as well. The importance of context when designing sounds is one such possibility. It is likely that matching the sound to the aesthetic context of the game will provide a better experience for players. However, no concrete claims can be made until further experiments have been conducted within those specific genres.

It is likely, however, that the characterizations of abstract and realistic sounds are applicable to all genres of game. The interviews in Study 2 were conducted in more general terms, rather than being confined to a specific genre. To verify this, a follow-up interview study should be performed, asking participants about different kinds of sounds in other genres. Based on the previous results, it is expected that these characterizations would not vary a great deal. There is also no indication that either type of sound should be heavily favoured or avoided in other types of games. This is another area for further research, in terms of the applications of abstract and realistic sounds in different genres of games, including both traditional genres as well as those within casual and mobile games as well.

6.5 LIMITATIONS

The limitations of each experimental study have been previously outlined thoroughly in their respective chapters. However, in general, it must be stated that this research is only relevant to the specific cases of sounds for health management and environmental awareness in FPS games. The results obtained here may not be relevant to other genres of games, or other sound design patterns within an FPS. There are many elements of both informative game audio and the player experience that are still not fully understood, and thus it is impossible to make broad generalizations about the information learned from this series of studies.

The work in this thesis is also limited by the relatively small number of participants in each study. Although most of the statistically significant results, such as awareness of health in Study 1, and the perception of health in Study 3, has a high level of significance, it is possible that the limitations of sampling previously discussed in each chapter had an influence on the results. Study 2 in particular could have benefit from a larger sample size, but it was difficult to arrange 45 minute long interview appointments with professionals in the games industry. In addition, a low sample size is common in qualitative studies.

Although the game developed for use in this thesis was useful for the studies performed, its use is limited in that it is not as robust or extensible as it could be. It is only useful for measuring differences in sound in the context of FPS gameplay. While this was acceptable for the purposes of this thesis, it requires additional development to make the logging processes more modular and user-friendly, as well as to increase the amount of features and genres of games that it is able to test. With some additional focus on this tool, it could become more useful to both academics and industry professionals for the rapid testing of game sounds within a desired context.

Furthermore, the experiments conducted in this thesis did not account for the preference of players, in terms of what sounds they would prefer to hear. All of the feedback audio used was selected by the experimenter with the intent of emulating the typical sounds heard within those contexts. Therefore, there may be an unknown effect of subjective player preference regarding types of feedback audio, and this is addressed when discussing future research opportunities in the following section.

6.6 future work

Moving forward, additional work needs to be performed on the game used throughout this thesis. To make its processes extensible to other contexts, all of the logic used to manage the sounds within the game scene should be refactored into an object that manages all of the sounds within the level. This would increase the usability of the software to allow for both a more complete array of sounds to enable, disable, and change, but decrease the amount of time needed to perform any of those actions. Aside from improving efficiency, the logging portion of the game could also be improved by incorporating switches for all possible logged events, such that an experimenter could easily tell the game which events and values they are interested in recording. By making these improvements, it would become possible to use *Unity 3D*'s prefab system to export both the sound manager and log manager objects to self contained and self sufficient "building blocks", usable in any game project..

In terms of informative sound research, the most obvious place to begin additional work is using the same methodology as in Study 3, examining some of the other informative sound design patterns as identified by Ng and Nesbitt [53]. Afterwards, it would be possible to examine each in greater detail, and both add to and refine the proposed list of game sound design guidelines. The work in this thesis has demonstrated that there can be a significant difference between the effects of these types of sounds within a health perception context, and it may therefore follow that there are significant effects in other contexts.

It is worth exploring the properties of abstract and realistic sounds further. While an initial definition has been proposed in Chapter 4, it does not offer any meaningful insight as to how these fit into the existing taxonomies of dynamic sound [13] and transdiegesis [32]. Given the demonstrated usefulness in understanding the concepts of abstract and realistic sound, it follows that a refined and complete picture of their role in the grand scope of game sound design is necessary.

Finally, all of the sounds used in the experiments were determined by the experimenter. In the future, it would be worthwhile to conduct a study which allows the participants to choose what sounds they want to hear in the game. By allowing the choice of abstract or realistic sounds for various types of feedback, it would be possible to ask why each choice was made in greater detail, thus leading to a deeper understanding of both the types of sounds as well as the feelings of players towards them.

6.7 Conclusions

Based on the work outlined in this thesis, I have shown there can be a distinction between the effectiveness of abstract and realistic feedback audio in FPS games. Although there are not always significant effects based on the type of audio used, there are experiential differences between the two when used to provide information on a player character's level of health in the context of FPS games. By continuing to study and understand these types of sounds and their properties, academia can inform the commercial game sound design community in creating sounds that provide better conveyance of information to players, in turn reducing the possibility of player frustration and confusion. Much work still remains to be done, but this thesis has taken important steps towards a more complete understanding of informative game audio and found that it is worth examining further.

Part IV

APPENDIX

A

APPENDIX A: QUESTIONNAIRES

A.1 INTRINSIC MOTIVATION INVENTORY

IMI [39]

Please indicate whether you agree or disagree with the statements provided (1 = strongly disagree, 3 = neither agree nor disagree, 5 = strongly agree.)

```
I enjoyed this game very much.
1       2       3       4       5


Playing the game was fun.
1       2       3       4       5


I would describe this game as very interesting.
1       2       3       4       5


While playing, I was thinking about how much I enjoyed it.
1       2       3       4       5


This game did not hold my attention.
1       2       3       4       5


I think I am pretty good at this game.
1       2       3       4       5


I am satisfied with my performance in the game.
1       2       3       4       5


After playing the game for a while, I felt pretty competent.
```

```
1       2       3       4       5


I am pretty skilled at this game.

1       2       3       4       5


I couldn’t play the game very well.

1       2       3       4       5


I put a lot of effort into the game.

1       2       3       4       5


It was important for me to do well at the game.

1       2       3       4       5


I tried very hard while playing the game.

1       2       3       4       5


I didn’t try very hard at playing the game.

1       2       3       4       5


I felt tense while playing the game.

1       2       3       4       5


I felt pressured while playing the game.

1       2       3       4       5


I was anxious while playing the game.

1       2       3       4       5


I was very relaxed while playing the game.

1       2       3       4       5
```

A.2 POSITIVE AND NEGATIVE AFFECT SCHEDULE

PANAS [64]

Please indicate to what extent you feel this way right now (1 = Very slightly/Not at all, 5 = Extremely), reflecting upon your past play session.

```
Interested
1    2    3    4    5

Distressed
1    2    3    4    5

Excited
1    2    3    4    5

Upset
1    2    3    4    5

Strong
1    2    3    4    5

Guilty
1    2    3    4    5

Scared
1    2    3    4    5

Hostile
1    2    3    4    5

Enthusiastic
1    2    3    4    5
```

Proud

1 2 3 4 5

Irritable

1 2 3 4 5

Alert

1 2 3 4 5

Ashamed

1 2 3 4 5

Inspired

1 2 3 4 5

Nervous

1 2 3 4 5

Determined

1 2 3 4 5

Attentive

1 2 3 4 5

Jittery

1 2 3 4 5

Active

1 2 3 4 5

Afraid

1 2 3 4 5

A.3 PLAYER EXPERIENCE OF NEED SATISFACTION

PENS [59]

Reflect on your play experiences and rate your agreement with the following statements (1 = strongly disagree, 3 = neither agree nor disagree, 5 = strongly agree.):

```
I feel competent at the game.
1       2       3       4       5

When playing the game, I feel transported to another time and place.
1       2       3       4       5

The game provides me with lots of interesting options and choices.
1       2       3       4       5

Exploring the game world feels like taking an actual trip to a new
    place.
1       2       3       4       5

I find the relationships I form in this game fulfilling.
1       2       3       4       5

When moving through the game world, I feel as if I am actually there.
1       2       3       4       5

Learning the game controls was easy.
1       2       3       4       5
```

```
I am not impacted emotionally by the events in the game.

1       2       3       4       5


I feel very capable and effective when playing.

1       2       3       4       5


The game was emotionally engaging.

1       2       3       4       5


The game lets you do interesting things.

1       2       3       4       5


I experience feelings as deeply in the game as I have in real life.

1       2       3       4       5


I find the relationships I form in this game important.

1       2       3       4       5


When playing the game I feel as if I was part of the story.

1       2       3       4       5


The game controls are intuitive.

1       2       3       4       5


When I accomplished something in the game, I experienced genuine
    pride.

1       2       3       4       5


My ability to play the game is well matched with the game's
    challenges.

1       2       3       4       5
```

I had reactions to events and characters in the game as if they were real.

1 2 3 4 5

I experienced a lot of freedom in the game.

1 2 3 4 5

I don’t feel close to other players.

1 2 3 4 5

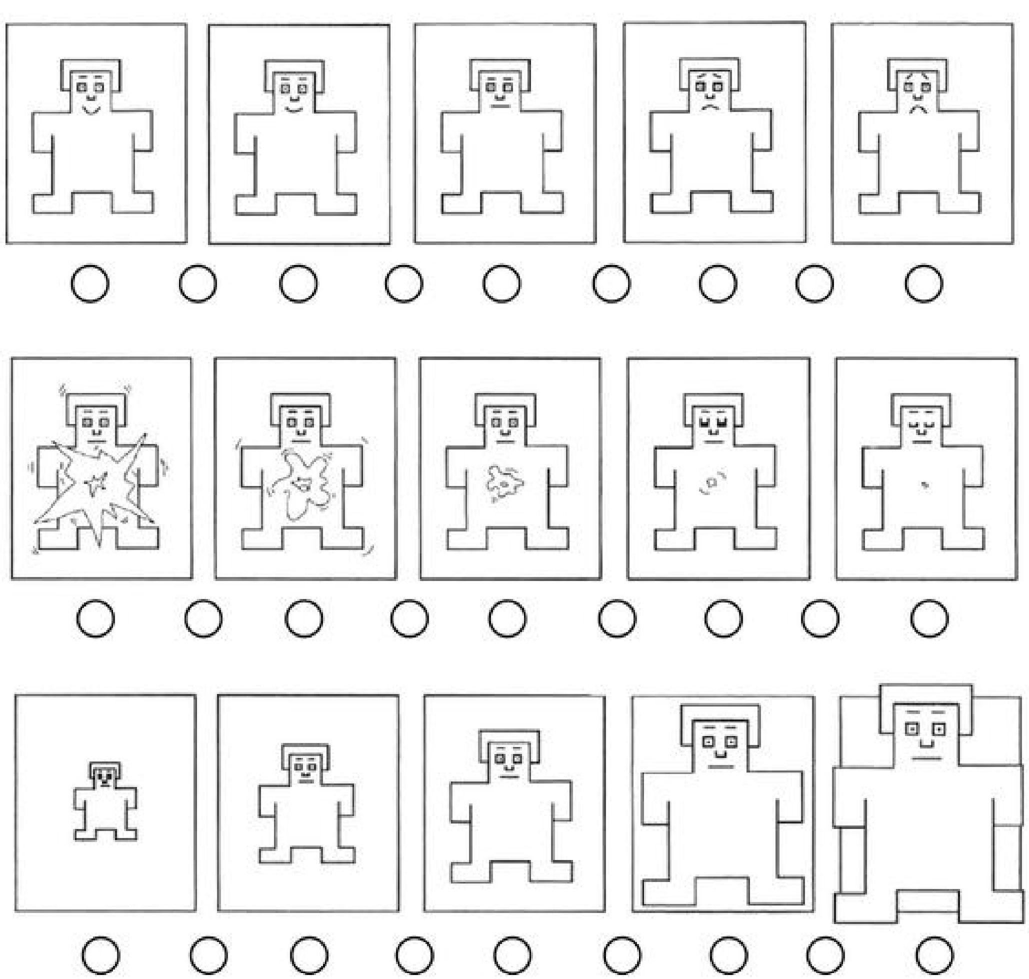
When I wanted to do something in the game, it was easy to remember the corresponding control.

1 2 3 4 5

A.4 SELF ASSESSMENT MANIKIN

SAM [9]

Please indicate how you feel in relation to the following:



A.5 STUDY 1: DEMOGRAPHICS

Demographics

```
Please indicate your gender:

Male            Female
```

```
Please enter your age:
[               ]

How much experience do you have playing video games? 1 = No
    experience, 7 = Very exprienced
1       2       3       4       5       6       7

Approximately how many hours per week do you spend playing video
    games?
[               ]

How much experience do you have playing first person shooter games? 1
     = No experience, 7 = Very exprienced
1       2       3       4       5       6       7
```

A.6 study 1: additional questions

Please answer the following based upon your previous play session.

```
How fun was the game? 1 = Not at all, 5 = Very fun
1       2       3       4       5

How aware were you of your health being low? 1 = Not at all, 5 = Very
     aware
1       2       3       4       5

How bothered were you by dying in the game? 1 = Not at all, 5 = Very
    bothered
1       2       3       4       5
```

A.7 STUDY 2: DEMOGRAPHICS

Demographics

```
Please indicate your gender:
Male            Female

Please enter your age:
[               ]

How much experience do you have playing video games? 1 = No
   experience, 7 = Very exprienced
1       2       3       4       5       6       7

Approximately how many hours per week do you spend playing video
   games?
[               ]

How much experience do you have designing games? 1 = No experience, 7
    = Very exprienced
1       2       3       4       5       6       7

Do you have any hearing impairments?
Yes             No              Prefer not to answer
```

A.8 STUDY 3: DEMOGRAPHICS

Demographics

```
Please indicate your gender:
Male            Female
```

Please enter your age:

[ ]

How much experience do you have playing video games? 1 = No experience, 7 = Very exprienced

1 2 3 4 5 6 7

Approximately how many hours per week do you spend playing video games?

[ ]

How much experience do you have playing first person shooter games? 1 = No experience, 7 = Very exprienced

1 2 3 4 5 6 7

Do you have any hearing impairments?

Yes No Prefer not to answer

B

APPENDIX B: INTERVIEW QUESTIONS

B.1 STUDY 1 INTERVIEW QUESTIONS

1. Did you notice a difference between the two game sessions that you played? Explain.
2. Was one play session more difficult than the other? Why or why not?
3. How important do you feel that audio cues are in games? Why or why not?
4. In one condition, there were some sounds missing. How did you feel about that and what did that mean for you?
5. Think about your character's health in the game. How did you judge whether you were in danger of dying or not?
6. How important is audio in terms of judging your health? Why or why not?
7. How low should your health be before you start hearing a noise to alert you of danger?
8. What kind of sound do you think should be used to alert a player of low health?
9. Should you change the volume of the alert sound based on the player's level of health? Why or why not?
10. Should you change the frequency of the alert sound based on the player's level of health? Why or why not?

B.2 STUDY 2 INTERVIEW QUESTIONS

1. What kinds of games do you like to play?
2. What types of sounds do you consider important when playing a game?
3. What difference do you see between music and sounds in video games? How do you think they are used? Have noticed them being used in a particular way?
4. How would you define *abstract audio* in games?
5. Can you provide some examples of *abstract audio* in the games that you have played?
6. How would you define realistic or *non-abstract audio* in games?
7. Can you provide some examples of *non-abstract audio* in the games that you have played?
8. Of these two categories, realistic or non-abstract sounds and abstract sounds, do you think one is better to use than another? In what cases would they best be used?
9. Can you think of some situations in which *abstract audio* would be more suited to a game event?
10. Can you think of some situations in which realistic or *non-abstract audio* would be more suited to a game event?
11. Do you think that having more realistic or *non-abstract audio* would contribute to a greater degree of player immersion or involvement in a game? Why or why not?

B.3 STUDY 3 PHASE 1 INTERVIEW QUESTIONS

1. Which sound did you prefer, the beeping or the footsteps? Why?
2. Which sound did you think was more useful for the task, the beeping or the footsteps? Why?
3. Did you feel that you could accurately hit the target? Why or why not?
4. Did you feel that you could quickly identify the source of the sound? Why or why not?
5. Did either sound make you feel anything unexpected? If so, please explain.

B.4 STUDY 3 PHASE 2 INTERVIEW QUESTIONS

1. Which sound did you prefer, the beeping or the heartbeat? Why?
2. Which sound did you think was more useful for the task, the beeping or the heartbeat? Why?
3. Did you feel that you could accurately judge your level of health? Why or why not?
4. Did either sound make you feel anything unexpected? If so, please explain.

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