DOES HORROR GAME MUSIC MAKE YOU ANXIOUS? EXPLORING HORROR MUSIC'S EFFECT ON PLAYERS: A MIXED METHODS STUDY

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Abstract

Anxious and suspenseful musical elements are abundant in horror video games, and a lot has been done in studying the ways this kind of music is made, and how it presents itself in-game. In video game studies fear and anxiety inducing elements are seen as key emotional elements in the horror genre.

Most studies on music and anxiety focus on music's ability to reduce anxiety in various situations. Despite this, fear, for example, is a typical emotion featured in the study of musical emotions and music has also been found to be effective in generating and amplifying suspense, as well as anxiety and stress. Video games also bring a noteworthy dimension into play through interaction and immersion.

Music has a significant impact on a player's actions and the intensity of the emotional experience and ways to analyze player behavior have been developed in the study of human-computer interaction and games. Mixing those methods with previously established psychological and musicological models and research is a current issue for game and game music research in general. Combining interdisciplinary measures in the study of video games also brings in new possibilities for surrounding fields. This study aims to answer how well anxious musical elements and sound design induce anxiety in a video game context and how experiencing video game anxiety affects player behavior. The study is also a good opportunity to compare how well different types of data succeed in detecting and measuring anxious responses.

A mixed-methods study was formulated to test the research questions. The participants played a specifically designed video game with music as the sole variable. Participants were assigned one of three musical scenarios: anxious, neutral and control (no music). Physiological reactions (HRV, SCL, SCR) were measured and compared to player in-game movement data. Interviews for subjective appraisals of the experience were also conducted.

The anxious scenario saw a significant change in SCL compared to the neutral and control scenarios. A significant increase in horizontal camera movement was also observed for the anxious scenario compared to other scenarios. On average, the players in the anxious scenario were the slowest to complete the game. The anxious scenario also produced visually distinct in-game movement patterns, possibly worth further study. Player performance in flaw detection got worse as more anxious musical elements were presented. The players who played the anxious scenario also had the most fun.

Keywords horror, horror music, video games, anxiety, horror games, immersion, video game music, mixed methods

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Tiivistelmä
Kauhupelit sisältävät runsaasti ahdistavia ja jännittäviä musiikillisia elementtejä, ja kauhupelimusiikkia on tutkittu sekä tuotantoprosessien että peleissä ilmenemisen konteksteissa. Videopelitutkimuksen saralla pelkoa ja ahdistusta aiheuttavat musiikilliset elementit ovat kauhupeleille keskeisiä. Useimmat musiikkia ja ahdistusta koskevat tutkimukset keskittyvät musiikin kykyyn lievittää ahdistusta eri tilanteissa. Tästä huolimatta esimerkiksi pelko on tyypillinen kohde musiikillisten tunteiden tutkimuksessa, ja musiikin on myös havaittu synnyttävän sekä vahvistavan stressiä, jännitystä ja ahdistusta tehokkaasti. Pelaamiseen olennaisesti liittyvä vuorovaikutteisuus sekä uppoutuminen (immersiivisyys) tuovat videopelitutkimukseen huomionarvoisen ulottuvuuden.
Musiikilla on merkittävä vaikutus pelaajan toimintaan, ja tunnekokemuksen intensiteettiä sekä pelaajan käyttäytymistä on pyritty analysoimaan erilaisilla malleilla, joita on kehitetty ihmisen ja tietokoneen välisen vuorovaikutuksen (Human-Computer Interaction) sekä pelien tutkimuksen saroilla. Näiden menetelmien yhdistäminen aiemmin vakiintuneisiin psykologisiin ja musiikkitieteellisiin malleihin ja käytäntöihin on ajankohtainen ilmiö sekä peli- että pelimusiikkitutkimuksen suhteen. Tieteidenvälisten menetelmien hyödyntäminen videopelien tutkimuksessa luo uusia mahdollisuuksia myös sitä ympäröiville aloille. Tämän tutkimuksen tavoitteena on selvittää, kuinka tehokkaasti ahdistavat musiikilliset elementit sekä äänisuunnittelu todella aiheuttavat ahdistusta pelaajassa, sekä miten koettu ahdistus vaikuttaa pelaajan käyttäytymiseen pelin sisällä. Tämä tutkimus luo myös mainion tilaisuuden vertailla, kuinka tehokkaasti erityyppisten mittausmenetelmien avulla voidaan havaita ja mitata ahdistuneita reaktioita.

Tutkimuskysymysten testaamiseksi laadittiin sekamenetelmätutkimus. Osallistujat pelasivat yksinomaan tutkimusta varten kehitettyä videopeliä, jossa musiikki oli ainoa muuttuja. Jokaiselle osallistujalle annettiin yksi kolmesta musiikillisesta skenaariosta: ahdistava, neutraali tai kontrolli (ei musiikkia). Fysiologisia reaktioita (HRV, SCL, SCR) mitattiin pelaamisen aikana, ja verrattiin pelidataan pelaajahahmon liikkeistä. Osallistujia myös haastateltiin kokemusten subjektiivista arviointia varten.

Ahdistavassa skenaariossa SCL kohosi merkittävästi neutraaliin ja kontrolliskenaarioon verrattuna. Ahdistavassa skenaariossa myös vaakasuuntainen kameraliike lisääntyi huomattavasti muihin skenaarioihin verrattuna. Ahdistuneen skenaarion pelaajat olivat keskimäärin hitaimpia pelin läpipeluussa. Ahdistavasta skenaariosta havaittiin myös silmiinpistäviä pelin sisäisiä liikekuvioita, jotka voisivat olla kiinnostava jatkotutkimuksen aihe. Mitä enemmän ahdistavia elementtejä musiikkiin lisättiin, sitä heikommin ahdistavan skenaarion pelaajat havaitsivat vikoja ympäristössä. Ahdistavan skenaarion pelanneilla pelaajilla oli kuitenkin myös hauskinta.

Asiasanat

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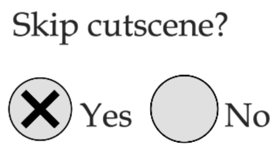
Additional information

PREFACE

In the Spring of 2021, two musicology students found themselves working together, building a game art exhibition for the Jyväskylä art museum. They shared an appreciation for video game music and were both starting to write their bachelor's theses at the time. After a few talks they found...



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This is a joint thesis, and both authors had their own main responsibilities within the project. Our collaboration was smooth, and all the big decisions concerning the thesis were made together. Enja's main responsibility was to research and write about game music and horror games. She was also in charge of the physiological data collection and analysis, as well as creating the music and sound design for the game that was the focus of the thesis. Santeri was mainly responsible for the psychology, music psychology, human-computer-interaction and immersion aspects of the literature review. He also programmed the game and was responsible for collecting and analyzing the gameplay data. Everything else, like other text, game concept and research design was a joint effort of both authors.

We'd like to first and foremost thank our supervisor Geoff Luck for his superb support and invaluable insights. We also want to thank the wonderful Henna-Riikka Peltola for believing in us and giving this project a mild sign of approval in the first place. Her guidance has been deeply appreciated throughout our studies. A huge thank you to Markku Pöyhönen for helping us organize the research and get the resources and equipment we needed. Thank you to all the peers, teachers, researchers and staff members at Musica for making it a nice place to study. Thanks to Ylä-Ruth for the cheap coffee and for being open even after the library closes.

In Jyväskylä, 14.8.2024
Enja Heikkilä & Santeri Salmirinne

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1 INTRODUCTION

Anxious and suspenseful musical elements are abundant in horror video games, and a lot has been done in studying the ways this kind of music is made in the game industry, and how it presents itself in-game. The question of anxious video game music lies at the crossroads of many different research areas. Anxiety has been studied extensively in different fields of psychology, and its mechanisms in that context are well known both as an emotion, as well as a disorder. In video game studies fear and anxiety inducing elements are seen as key emotional elements in the horror genre. The related fields of human-computer interaction, musicology, and psychology have a long-lasting interest in the systematic study of emotions. Negative emotions like anxiety, however, have perhaps understandably not made the key interest of scholars within the field, who instead have focused more on positive studies. It is fascinating that a popular genre of games and game music is heavily based on creating these so-called negative emotional experiences such as fear and anxiety, but the effectiveness of the genre's musical efforts has gone largely untested. When looking up "music and anxiety" in practically any database of scientific articles, the studies that show up most likely focus on testing music's ability to reduce anxiety in various situations. There have been studies that have aimed to reduce the effect of anxious situations with the help of music (e.g., Bradt et al., 2013; Seinfeld et al., 2016; Kanehira et al., 2018). On the game side of things, a similar search presents us with projects like *MindLight* (Wols et al., 2018; Schoneveld et al., 2016), that aim to teach children to cope with anxiety using biofeedback technology.

Despite the overwhelming majority of quantitatively oriented related studies being focused on reducing experiences like anxiety, there has been some of studies focusing on the opposite as well. Fear is, for example, a typical emotion featured in the study of musical emotions (e.g., Gosselin et al., 2007; Krumhansl, 1997) despite the compelling arguments against music's ability to express it (Cespedes-Guevara & Eerola, 2018). Music has also been found to be effective in generating and amplifying suspense (Cohen, 2001), as well as anxiety and stress (Thayer & Levenson, 1983) in the context of films. Notably, no studies were found that examined the effectiveness of negatively valanced music itself in a video game setting that would have applied a quantitative approach.

Video games also bring a noteworthy dimension into play through interaction and immersion. A study by Lavoie and colleagues (Lavoie et al., 2021) suggests that, if immersive enough, video games could cause PTSD-like effects on players by amplifying the importance of the gameplay and the emotions arising from that (Lavoie et al., 2021). Generally, immersion seems to correlate with the intensity of the emotional experiences, and vice versa, in a feedback loop between the player and the game (Calleja, 2011). Highly immersive virtual reality games and applications have been widely studied in a therapy setting to simulate real-life scenarios in treating, for example, anxiety disorders (e.g., Kwon et al., 2013; Carl et al., 2019). Highly immersive virtual reality is however not a requirement for a therapeutic game, and more traditional games such as MindLight (Wols et al., 2018; Schoneveld et al., 2016) as well as Magis (Keinonen et al., 2023) already take advantage of game elements in helping children deal with anxiety or other kinds of mental problems. The application of music therapy elements as well as any and all knowledge of how, for example, the experience of anxiety works in such games could prove itself highly useful in developing better applications and games in the future. The results of this study could also help for example game companies to better interpret gameplay data from their users.

The study of human-computer interaction has developed methods to analyze and study players' behavior and experience in games (e.g., Ravaja et al., 2006; Schertler et al., 2019) and combining those methods with previously established psychological and musicological models and research seems to be at the forefront of game and game music research in general (see Williams, 2021). Methods of analysis specifically intended for reviewing video game music are still sparse (Medina-Gray, 2019), and developing models that serve well both music and video games is in order. Combining interdisciplinary measures in the study of video games also brings in new possibilities for the surrounding fields of study as well. The immersiveness and the "natural" placement of music in virtual environments can bring in new viewpoints for researchers of musical emotion tackling the debate between what are "real emotions" and what are "artistic/musical emotions".

The following research questions were formulated:

- Can anxious musical elements and sound design alone actually induce anxiety in a video game context?

- How does experiencing video game anxiety affect player behavior?

- How well do different types of data, such as physiological vs. subjective measures, succeed in detecting and measuring anxious responses?

2 BACKGROUND

Horror is one of the most popular video game genres. Fearful and anxious elements in horror games have the ability to captivate players time and time again, and well-designed horror games offer powerful emotional experiences. Horror is far from a new invention since listeners have been scared around campfires by terrifying monster stories for a long time. Elements of suspense and horror can also be seen for example in the classic tag-based chasing games such as “British bulldog” or “The black man”. If a player is caught, they join other catchers to catch the players. This kind of simple catching game does not involve deep strategy, and it cannot be survived. Few people enjoy the fear of getting caught outside the game context, but nonetheless avoiding getting caught is almost always fun and enjoyable in the form of a game.

Sound and music have also been used for scaring and terrifying for a long time. Good examples of scaring opponents on the battlefield by sound could be the pounding of grand marching drums or the Aztecs' "death whistle" that produces a sound resembling a human's painful scream. The signaling of horror elements plays an important role in both horror games and outside the genre. The enemy is often recognized as scary, and by listening the player can make a situational assessment even before seeing the actual sound source (van Elferen 2016a, p. 41). Preparing to detect and deal with threats is also argued to be the function of the human anxious response on an evolutionary level (Bateson et al., 2011), and the underlying neurological mechanisms are well studied. Fearful and anxious responses are closely associated with the amygdala (Banich & Compton, 2018), and similar responses have been found in connection to fearful music and vocalization as well (Aubé et al., 2015).

Music has a significant impact on a player's actions and especially on the strength and intensity of the emotional experience when playing games (e.g., Calleja, 2011; Jørgensen, 2017). Horror games use a lot of resources to incite fear and anxiety in the player, and therefore they offer an excellent opportunity to explore these emotions from both the player's and the game development's perspectives. Although anxiety and fear are not traditionally considered among the most significant emotions in music emotion research, their mechanisms are already well-known from a clinical and neuropsychological perspective. The study of musical emotions has mainly focused on positive emotions such as joy or love (Peltola & Vuoskoski, 2022). Therefore, it is fascinating that a popular genre of game music is heavily based on negative emotions such as fear and anxiety. Video games also offer a distinct musical experience from, for example, film music due to their interactive nature; the players' role is comparable to an actor in a play, as players' actions have a role in how the experience shapes up to be (Calleja, 2011). A lot of different data can be collected on human behavior and emotional experiences while gaming, and video game music creators have at their disposal a vast arsenal of proven composition techniques and musical ideas to achieve the desired emotional reaction (Heikkilä & Salmirinne, 2022). The aim is to draw from these extensive musical libraries, and see how well these ways of emotional communication, often created by field professionals relying heavily on their intuition, actually perform.

The question of anxiety inducing video game music lies at the crossroads of many different research areas. Anxiety has been studied extensively in different fields of psychology, and its mechanisms in that context are well known both as an emotion as well as a disorder. In video game studies fear and anxiety inducing elements are seen as key emotional elements in the horror genre. This literature review section combines the most relevant findings from our bachelor's thesis' (Heikkilä, 2022; Salmirinne 2022) with some additional points important for the current study. Literature was gathered mainly using the jyu.finna.fi -search (that has access to databases such as SAGE and EBSCO among others) and Google Scholar. The reference lists of central sources in this paper were also inspected to cast our net a bit further.

2.1 Horror video games

Horror as a game genre is not as easily defined as one might at first glance. It is commonly accepted that the genre exists, and that players can easily tell if a game is in the horror genre or not. Since horror video games draw a lot from horror films, the use of typical horror film tropes is one key element of the horror game genre, but simply looking at the themes and iconography is not enough to determine which type of game is being played. (Perron, 2018.) Typical horror themes and ideas are for example reference "to the supernatural, the abnormal, to mutilation, blood, gore, the infliction of pain, death, deformity, putrefaction, darkness, invasion, mutation, extreme instability, and the unknown" (Martin, 2019, p. 2). Horror elements are also present in video games outside the genre, and many games can be scary without fitting categorically to the horror genre.

Many horror games also promote a distinct style of play that is most closely associated with the horror genre specifically, that being survival horror. The genre has two main sub-genres: action-based fighting games, where the player is encouraged to face their fears and fight, and survival horror games, where the player should lean towards a stealth strategy, hiding and escaping from the enemy. This division could be made from the viewpoint of resources: does the player have a weapon? Are there enough resources? Is the player character able to heal? And so on. Based on the available resources, the player can either feel powerful enough to encounter enemies, or on the other hand, highly vulnerable. (Perron, 2018.) The survival-horror approach almost seems like an elaborate game of tag within a digital game, coming back to the earlier examples of yard games mentioned in the introduction, such as British bulldog.

Overall, the main definitive focus in the horror game genre is to evoke the feelings of fear and/or anxiety (and more complex related emotions) in the player. Horror games, and horror media in general, achieve this in a way that allows for experiencing these emotions in an enjoyable way (Martin, 2019). Perron also stresses the distinction to be made between horror in art and real existential horror that has a real-life evolutionary purpose (Perron, 2018). Again, many people enjoy playing horror games although feeling fearful or anxious is from a biological viewpoint always a negative reaction (Huron, 2006). How can it be enjoyable? Huron (2006) tries to answer this question by discussing a psychological experiment where amateur basketball players were asked to take shots from different locations around the basketball court, and rate how good each shot felt. Results showed that the players felt the most dissatisfied when they missed an "easy" shot, and most satisfied when they scored shots that they felt were the most difficult. Based on this, Huron writes that "unexpected fortune or misfortune causes the biggest emotional responses." (pp. 21–22.) When experiencing negatively valenced emotions such as fear or pain, the body releases opiates which allows the body to function in a state of crisis, and even if the initial cause for this reaction – for example, getting scared by a zombie who suddenly appeared on a screen – turns out not being a "real" threat, this release happens either way (Huron, 2006, p.23). As anxiety seems to lack a clear target and is related to something happening in the future, the reaction wouldn't occur in an anxious state, but if the anxiety results in suddenly getting really scared by a zombie, the reaction would follow. This again makes enjoying horror content, and more specifically, enjoying highly interactive horror games more sensible. Imagine a player playing a horror game, feeling focused and immersed, palms sweating and heart racing from all of the pressure that has been accumulated via scary visuals and sounds, dark and claustrophobic environment, limited resources, and a constant thought of possibly getting killed at any moment. When the player then manages to narrowly escape a nearing monster or successfully shoot a zombie who suddenly appeared from their left, they will likely feel good, getting a rush of excitement and relief at the same time, and if they fail and die, they could feel relieved that the situation was over and there weren't any consequences outside the game's world. They can always just start over and try again.

2.2 Immersion

Video games differ from other media like movies or theatre plays in the fact that the player (= audience) has an active role in how the experience shapes up. Players "do not merely consume a pre-established piece of media, but instead are active participants in the creation of their experience" (Calleja, 2011, p. 56). McGloin, Farrar & Krcmar (2013) define immersion as "a feeling of virtual involvement", and that it requires the user's behavior to be "translated into the gaming environment" (McGloin, Farrar & Krcmar, 2013). This idea of user behavior translating into the gaming environment is central to this study as well, as the aim is to analyze player movement data as indicative of the players own experience.

As mentioned in the introduction chapter, immersion seems to correlate with the intensity of the emotional experiences, and vice versa, in a feedback loop between the player and the game (Calleja, 2011). Highly immersive virtual reality games and applications have been widely studied in a therapy setting to simulate real-life scenarios in treating for example anxiety disorders (e.g., Kwon et al., 2013; Carl et al., 2019). Video game music also has an effect on immersion, and for example van Elferen's (2016a) model of game musical immersion has clear overlap with Calleja's (2011) model of involvement, especially in the categories of *affective involvement, narrative involvement,* and *kinaesthetic involvement.* (Salmirinne, 2022.) (For a more in-depth analysis of anxiety, music, and immersion see: Salmirinne, 2022)

2.3 Anxiety

Fear and anxiety are often spoken of as two sides of a single phenomenon, and clinically they are both usually combined under anxiety disorders. Anxiety shows itself neuroscientifically as a heightened state of vigilance in anticipation or response to a threat where danger is not clearly imminent, while fear reactions seem to be higher in intensity as well as last for a shorter period of time compared to anxiety (Sylvers et al., 2011). Anxiety has also been shown to have a negative effect on cognitive performance, as it seems to increase the "significance" of outside stimuli, thus taking away resources from executive functions (Eysenck et al., 2007). The physical symptoms of anxiety disorders usually show themselves as muscle tension, restlessness, as well as other stress-related symptoms, and the American Psychiatric Association also writes in their DSM-

5 classification that regular short-term anxiety is oftentimes stress-related (American Psychiatric Association, 2015). Anxiety as an emotion only differs from anxiety as a disorder in the frequency with which the anxious emotions come in (Banich & Compton, 2018), so it is fair to say that the theories from clinical psychology that concern themselves with anxiety as a disorder are valid in their descriptions of anxiety outside the clinical context aswell.

The reason anxiety was chosen to act as *the* horror game music emotion also lies in the difference between fear and anxiety. Cespedes-Guevara and Eerola (2018) argue that because instrumental music cannot specify its target, purely musical emotions cannot be target specific. This would exclude fear from the list of musical emotions, but anxiety on the other hand fits the description perfectly, as it is characterized by nonspecificity in its targeting. This of course does not mean that fear would not be present in the horror soundscape at all, as anxiety does seem to promote fearful responses to potential threats as well as fear of potential threats that have yet to be identified completely fits the description of anxiety. The important distinction is that music's role in all of this is to create anxiety, and it is up to other mediums to turn that into fear.

2.4 Music and anxiety

The study of musical emotions specifically has for a long time focused on mostly positive emotions, and only recently has the study moved towards more negative musical experiences (e.g., Peltola & Vuoskoski, 2022; Ackermann & Merrill, 2022), like anxiety. When looking up *music and anxiety* in practically any database of scientific articles, the studies that show up most likely focus on testing music's ability to reduce anxiety in various situations (e.g., Bradt et al., 2013; Seinfeld et al., 2016). Seinfeld & company for example, introduced music as a "potent emotional regulator" in their study that examined "the influence of music on anxiety induced by fear of heights" (2016, p. 1). The study sees music's role in this case to be modulatory, and instead of inducing a more relaxed emotional state they claim music to have a limiting effect on the subjective experience of anxiety. Music has also been found to be effective in generating and amplifying suspense (Cohen, 2001), as well as anxiety and stress (Thayer & Levenson, 1983) in the context of films. Fear is also a typical emotion featured in the study of musical emotions (e.g., Gosselin et al., 2007; Krumhansl, 1997) despite the compelling arguments against music's ability to express it by Cespedes-Guevara and Eerola (2018).

The study by Thayer and Levenson (1983) approached background music from a similar point of view that dates back to the 1980's. This is an specifically interesting example for the current case of anxious video game music because this is one of the earliest examples of a study that tried and succeeded in increasing the anxious effect as one of the scenarios. However, since Thayer and Levenson's test, only a handful of studies that were found have approached anxiety and music in this way. This is in stark contrast to the large amount of research on horror music in the context of movies and video games. The idea of music as an emotional modulator, as portrayed by the likes of the mentioned Seinfeld or Thayer and Levenson, has been studied extensively. The idea is quite close to the way Cespedes-Guevara and Eerola (2018) as well as Robinson (2008) speak of music's (and in Robinsons case horror music's) tendency to truly communicate in many different affective states such as moods or attitudes.

2.5 Horror video game music

As well as being an important tool as a narrative element or expressing moods, music can also heavily influence player immersion and gameplay experience (e.g., van Elferen, 2016a; Munday, 2007), or act as a navigational or instructional tool for the player (e.g., Jøergensen, 2017; Grimshaw, 2011; Stevens, 2021; Berndt, 2019). Grimshaw et al. (2013) illustrate this with an example of game music that is intended to create atmosphere and not much else. The music combined with environmental sounds such as leaves rustling or wind, could indeed increase player immersion and interest, but have no effect on performance. They also argue that highly complex music can be distracting, supporting the arguments made by Stevens and Raybould (2014) of complexity in music being intentionally used to destabilize gameplay and distract players (Grimshaw et al., 2013, p. 302). It is typical for horror games specifically that certain musical features are included to destabilize the player; these include, for example, a lack of pulse or tonal center (Stevens & Raybould, 2014). A line can be drawn to Eysenck and colleagues (2007) study where they found that experiencing anxiety had a negative effect on cognitive performance, especially executive functioning, as it increased the significance of "outside" stimuli. Jøergensen (2017) also claims that the player's ability to absorb information can be disrupted when the music is removed. Based on a qualitative study she conducted among players, the lack of sound had a negative effect on the player's focus and immersion in a gameplay situation. (Jøergensen, 2017.) In different studies both the experience of anxiety, and the complete lack of sound can achieve a similar functionality in distracting the player, but they differ in where the player's attention is being directed. In Grimshaw and colleagues' (2013) study the player remains somewhat immersed in the game despite the distraction, whereas in Jøergensen's (2017) study the player is more so ejected from the game.

According to Berndt (2019), game music often affects player behavior in ways such as driving them forward or soothing them at different points of the game, while also leading the player to practice self-reflection, contemplation or understanding the consequences of their actions in complex game scenarios (Berndt, 2019, p. 199).

Munday (2007) argues that horror game music typically uses specific musical features to affect the player's behavior and psychological state, such as relying on heavy dissonance to "rack up the tension and put the player on edge". He highlights the argument originated by Whalen, that horror games tend to lack a state of safety, making players unable to relax. (Munday, 2007.) It is noteworthy that game music often draws heavily from film (Bernt, 2019), utilizing widely known methods such as the leitmotif, naturally used for narrative purposes, and often also for player guidance, helping in things like choosing gameplay strategy or finding objects. In their article about the features of anxious and terrifying movie music, Trevor et al. (2023) describe both in great detail. According to them, spacious harmonies and hollow textures that move between both high and low pitch are typical to anxious music, and it is often dynamically rather muted, distant and murky. Sound effects such as whispers are typical of anxious music, whereas terrifying music might feature sounds like banging, thunder, and so on. Both subtypes of music share features such as minor mode, dissonance, large sound level variability, wide pitch range and micro-structural irregularity in sound level and pitch. Unpredictability in dynamics and structure is also typical for both, often accompanied by a pulsing bass. (Trevor et al., 2023, pp. 390–391.)

According to Guy Michelmore, one of the most crucial decisions game composers must make early in the composition process is to determine how the music will react to gameplay and the player (2021, p. 67). Berndt (2019) writes: "Players do not wait for the music. Music has to follow." (p. 201).

Jesper Kaae also highlights the importance of composing and audio implementation while attempting to build a bridge between the vast knowledge of both composers and researchers. In addition to the music itself, the composition process includes a lot of technical work, matching parts and embedding them in the game. The key to game music's effectiveness is its dynamic nature; Kaae writes that dynamic music reacts to the player's actions, and most of the time it only takes on its true shape when a game is being played – making it adaptive, immersive and interactive. (Kaae, 2017.)

In a documentary explaining the development of the survival-horror game *The Last of Us* (Sony Entertainment, 2013), the audio team relied heavily on using silence as a tool (Sony Entertainment, 2014). For example, music could be left out of a gameplay situation where the player encounters a "clicker". Clickers are enemies that navigate by echolocation only, forcing the player to move in an extremely silent manner, for which the lack of music acts as a way to make the player highly aware of being a sound source. The team also explained that they intentionally used intense and fast percussion in some situations to create a sense of urgency for the player. (Sony Entertainment, 2014.) In his article, Bridgett (2021) supports this mechanic, arguing that the game's sparse way of using (quite minimalistic) music does enhance both player immersion and the emotional impact of key moments – for which he credits the development team and their thorough knowledge of their audience and player behavior

(2021, p. 116). Stevens (2021) also argues that a conflict between musical interactivity and gaming experience can arise, when "the approach to music, the systems and thresholds chosen are developed for the experience of an average player, but we know that approaches may differ markedly", followed by an example from the stealth game *Dishonored 2* (Bethesda Softworks, 2016), where players approaching it "with an aggressive playstyle will hear an awful lot of the high-intensity 'fight' music; however a player who achieves a very stealthy or 'ghost' playthrough will never hear it" (2021, p. 85). He also suggests that one of the most crucial features in video game music lies in its interactive nature, claiming that emotionally impactful game music needs to be crafted with high attention to its progression, adaptability and dynamics, and the variety of players' approach to gameplay needs to be thoroughly assessed in game development (Stevens 2021, p. 86). Berndt (2019) also supports this claim, arguing that linear music does not suit interactive narration, often seeming incoherent in the virtual world, easily disrupting the gameplay experience with harsh cuts, repetition and harsh transitions (p. 201).

Some horror games that are considered in literature as successful in using music and audio effectively include *Amnesia: The Dark Descent* (Frictional Games, 2010), for creating tension with audio cues expressing sanity (van Elferen, 2016a); *Dead Space 2* (Electronic Arts, 2011) for player guidance and emotional expression with audio (van Elferen, 2016a; Sweeney, 2016) and *The Last of Us* for effective use of silence and minimal music to create tension and emotional impact (Bridgett, 2021).

2.6 This study

Methods of analysis specifically intended for reviewing video game music are still sparse (Medina-Gray, 2019), and the varying methods of gathering data in studies such as the ones that are discussed in this chapter, lead to some confusion when it comes to the 'best' form of data to inspect, for example, a physical response to game music.

As discussed, anxiety and fear are tied together in many ways, and the way these emotions are measured is not an exception. The two differ from each other mainly by the duration of arousal, which is longer for anxiety while the fear response is shorter lived (e.g., Sylvers et al., 2011; MacLeod & Rutherford, 1992). This heightened state of arousal can be examined via changes in the autonomous nervous system by measuring, for example, heart rate (HR), heart rate variability (HRV), respiratory rate (RR), and galvanic skin response (GSR), which belongs under the umbrella term of electrodermal activity (EDA) (Kreibig, 2010). GSR components have been used as an indicator of stress and anxiety for a long time, and in this specific context it seems to have proven itself quite reliable, from older studies such as Thayer and Levenson (1983) to recent ones such as Baldini and company (2022) who examined the correlation between subjective measures of fear with physiological ones. The GSR data can be divided into tonic SCL (skin conductance level) and phasic SCR (skin conductance response) components, and an increase in activity of both of these components has been linked to high arousal levels (Lyrken & Venables, 1971; Critchley, 2002), and in a more detailed manner, stress and anxiety (Polat & Özen, 2023), as well as anxiety and fear (Kreibig, 2010). Moreover, these tonic and phasic components have been widely utilized biomarkers in musicological and ludomusicological studies, such as Nacke, Grimshaw, and Lindley (2010) with their study about sonic user experience in a first-person shooter game. Dana Plank (2021) also mentions skin conductance as a measurement of emotion in relation to video game experiences, and Ravaja et al. (2006) used a combination of SCL, SCR and HR measurements to assess emotional reactions to game events. A GSR analysis is also an accessible and inexpensive method of measuring arousal and emotional states (Benedek & Kaernbach, 2010; Critchley, 2002). Another data type for measuring anxious responses is heart rate variability (HRV). A decreased HRV level can indicate increased levels of stress or anxiety (e.g. Benchekroun et al., 2023; Tiwari et al., 2021). Moreover, decreased HRV with increased HR (heart rate) is a phenomenon common to anxiety (Kreibig, 2010).

As argued by Baldini et al. (2022), using subjective measures to balance out the results given by objective measures is often necessary, as many of the mechanisms of emotional arousal are often interwoven. For example, signs that indicate an increase in arousal can be from fearful or anxious stimuli, but it can also be the result of practically any kind of positive excitement or physical exertion, for example. These subjective measures can be as simple as interviews, but psychological inventories like the State-Trait Anxiety Inventory (STAI) are often used as well.

Fear and anxiety also have a studied effect on behavior (e.g., Sylvers et al., 2011; Lin 2017; Seinfeld et al., 2016) and connecting behavioral observations with subjective and physiological measures might prove useful. For example, if one would like to examine the effectiveness of anxious stimuli in a video game, they could try to analyze the player's movement patterns with the help of a method like Schertler and companies (2019), for example, and connect them with the corresponding emotion-related strategies or responses. The obvious benefit to using behavioral data is that it is a less invasive method of studying emotional responses compared to physiological measurements, so if theory can be established it can prove to be a good tool in the study of video game emotions in the future. An encouraging example is a study by Lin (2017), that found that the most common coping strategy to fear elements in a horror zombie survival game was in fact to approach the source. Sylvers et al. (2011) list approach as a characteristic strategy for anxiety. This leads to the conclusion that the fear elements in Lin’s study in fact managed to induce behavior that reflects distinctly anxiety in players, and not fear. This leads to a hypothesis that behavioral responses for anxiety could be accurately reflected by in-game behavior. The idea of the player’s experienced emotions being reflected in the gameplay relies on the assumption that a game reaches a sufficient level of immersion (see for example, Calleja, 2011; McGloin, Farrar, & Krcmar, 2013), and a lower level of immersion could be reflected by incongruence between gameplay data and emotional stimuli.

In terms of physiological data, three testable hypotheses were created. The first hypothesis was that heart rate variability (HRV) levels would decrease during gameplay with horror music, an effect that has been linked to stressful and anxious responses in previous studies (e.g., Benchekroun et al., 2023; Tiwari et al., 2021). The second hypothesis was that an anxious response to horror music would cause an increase in skin conductance level (SCL). The third hypothesis for physical data was that an anxious response would show an increase in the frequency of skin conductance responses (SCR). These hypotheses were formed based on previous literature (e.g., Kreibig, 2010; Polat & Özen, 2023; Lyrken & Venables, 1971).

Two hypotheses were developed for the in-game data. It was hypothesized that anxious music would make the players more actively look for potential threats in the game. This is based on Bateson, Brilot & Nettle's (2011) argument that preparing to detect and deal with threats is the function of the human anxious response on an evolutionary level. Similar deductions can be made from the paper by Sylvers et al. (2011) where they define anxiety as a heightened state of vigilance in anticipation or response to a threat where danger is not clearly imminent. Eysenck and colleagues also found that anxiety would increase the possibility of getting distracted by increasing the significance of outside stimuli (Eysenck et al., 2007). This kind of behavior could be detectable for example by looking at how much the players turned their camera during the gameplay session to scan their surroundings, or by the amount of back-and-forth movement by the player. As mentioned by Eysenck et alii (2007) experiencing anxiety could hinder executive function by increasing the importance of "outside stimuli". Based on this, it was hypothesized that increasing anxiety levels in the music will cause disorientation and make it harder for players to spot the flaws in the game. Looking at how long it took for players to complete the given task should give a good indication of game difficulty and players' success in learning the new task.

Subjective measures, such as interviews or questionnaires, should be able to help assess the research situation on a meta level and better interpret the results from the two other data types. No specific hypotheses were created for this data type. Following the example from Baldini et al. (2022), it should be possible to evaluate the validity of EDA measurements by seeing if they are in line with the subjective evaluation of experienced emotion. This approach could be applied to evaluate and interpret the results derived from both physiological and in-game data measures in this study.

So, to reiterate; the following hypothesis were made based on the literature, that, if true, would indicate an anxious response:

- Hypothesis 1: HRV levels will decrease with horror music

- Hypothesis 2: SCL will increase with horror music
- Hypothesis 3: Frequency of SCR peaks will increase with horror music
- Hypothesis 4: The players will more actively look around the game environment by turning the camera and moving their character with horror music
- Hypothesis 5: The players will spend a longer time completing tasks with horror music

2.7 Summary

In video game studies, fear and anxiety inducing elements are seen as key emotional elements in the horror genre. Horror games spend a lot of resources in achieving the desired emotional effects on the players, which makes horror games a topic of interest for anyone interested in the phenomena. Behind a scary or distressing gaming experience is often a unique combination of sound, image, and interaction between the player and the game.

A lot has been done in studying the ways this kind of music is made in the game industry, and how it presents itself in-game, but few studies have tested the effectiveness of horror game music in actually inducing these emotions in the player. Video games also offer a novel environment to these anxious musical experiences through immersion and interactivity. One gripe that was encountered with many psychologically oriented studies examining horror elements in video games is that they often neglected the game audio, and on the other hand many of the studies that examined horror game audio specifically did not yet combine psychological theories or approaches to their studies. Previous horror game studies often use pre-existing games in their research, and while it is important to use organic stimuli, creating specialized games for the purpose of better monitoring the interaction of specific game elements seems like the next step.

Our aim in this thesis was to conduct an empirical study that focuses on the question of whether horror game music on its own can induce measurable anxiety in the player, and if so, how will the player's anxious state affect their in-game behavior and strategy. The study can also shine light on how well different data types succeed in detecting and measuring anxious responses in a video game context. To address these gaps in research, the following research questions were formulated:

- Can anxious musical elements and sound design alone actually induce anxiety in a video game context?

- How does experiencing video game anxiety affect player behavior?

- How well do different types of data, such as physiological vs. subjective measures, succeed in detecting and measuring anxious responses?

A pragmatic mixed methods approach was deemed appropriate for the task at hand, and it combines three methods that represent the three disciplines (musicology, ludology, and psychology) well.

3 METHODS

3.1 Experiment setup

To address the research questions, a study was designed in which the participants would play a short video game developed solely to serve the study's purpose. Physiological data and gameplay data were collected, along with short interviews, during which the participants gave numeral as well as verbal answers to each question. ANOVAs were conducted for both the physiological data and gameplay data. Interviews were transcribed and numeral ratings were exported to a table form.

Three scenarios were created for the study: one with anxious music, another with neutral (or positive) music, and one without music, but with the same environmental sounds and sound effects as the other scenarios. Medina-Gray (2021) argues that the line between music and other sonic elements such as sound effects and environmental sound is often blurred – and with horror music, this separation can be even trickier. According to her, this dilemma plays a key part in the idea that music cannot be inspected as completely apart from other sound, and vice versa. The overall soundscape includes all sound, be it music, sound effects, environmental ambience or dialogue. Music, however, can include elements that could be seen as sound effects, but a line between the two can be drawn when said elements are immersed into the musical segments and purposes instead of purely being sonic counterparts to objects or actions. (Medina-Gray, 2021.) On the other hand, environmental sounds such as wind ambience can help bind music and sound effects together into a cohesive soundscape (Bessell, 2018). If all sound, including action-related sound effects and environmental sound would be removed from the non-musical scenario, as for example Jøergensen (2017) did with her study, one would have to take into account the possibility of ingame behavior and immersion being affected and altered by not only the lack of music, but also the lack of other sound. As argued by Medina-Gray, a key part in the interactivity and immersiveness of a game in relation to sound is that in-game actions have an appropriate, sonic equivalent (Medina-Gray, 2021). This led to the design choice of creating three scenarios for this study, in order to see how scenarios with different musical qualities differ in altering and affecting the emotional state and behavior of the player, as well as to see how the scenario with music and other sound compares to a scenario without music but with other sound. This way it was possible to observe music with particular qualities in comparison to other music, as well as the overall effects of the presence or lack of music without heavily compromising player interactivity and immersion.

3.1.1 Participants

The study followed the ethical principles of research with human participants and ethical review in the human sciences in Finland (Kohonen et al., 2019, pp. 8–10), and obtained ethical approval from the Human Sciences Ethics Committee.

Participants were recruited by advertising the study with posters placed on University of Jyväskylä's (JYU) Seminaarinmäki campus bulletin boards, advertisements on some JYU student email lists, and social media posts (LinkedIn, Instagram, Facebook, student WhatsApp groups) directed towards those in Jyväskylä interested in gaming or music. The aim was to recruit ~30 participants for the study.

15 participants filled in the Webropol form for the study, but two of them did not answer the follow-up email to arrange a time for the in-person participation. 13 participants attended the in-person session and played the game. The scenarios were named anxious (horror), neutral (pleasant), and control (no music). The scenario names were abbreviated to filenames and other data to be the first letter of each word, so for example all the participants in the anxious scenario would have the letter A designating the group they belonged to. The scenarios were assigned for the participants in an alternating chronological order, with the first participant getting scenario A, second N, and third C. The fourth participant would get scenario A again and so forth. One participant's data had to be dismissed from the analysis due to the corruption of the gameplay data that was recorded from their entry. Because of the lost data, it was concluded that the participant's physiological data and interview would also be discarded in order to maintain a balanced data structure. The one participant whose data was unusable got scenario C, and this was dealt with giving one of the participants scenario C when they were not supposed to. The alternating order was resumed for the remainder of the study. Each group had four complete data entries at the end of the study.

The participants were required to be 18 years of age, and in good basic health. For example, patients with heart problems were excluded from the study, so the data from measuring heart rate variability would remain valid. Similarly, anyone with diagnosed anxiety disorders were excluded to not have any bias in how well the "anxious" stimuli performs as well as avoiding any potential harm to the participants (e. g., panic attacks) due to the anxious stimuli or the research situation as a whole. The participants were not compensated in any way for their participation, besides the experience of playing the game. See exclusion criteria in attachment 1.

3.1.2 Structure

The participants signed up for the study by filling in an online form, during which they were presented with, and asked to familiarize themselves with summaries of the research notification (containing the exclusion criteria) and the privacy notice before sending the form. They had the possibility of viewing the full documents of those as well, by links attached to the form. The online form also mentioned the broad topic of the study being the effects of emotions on gameplay performance, and that the content would have to do with horror games. After signing up, the participants were contacted by email to arrange a suitable time for their in-person participation. The participants were informed that they would sign a final consent form when they arrived at the study location.

The study took place in a room that had a 31,5" computer monitor with an office chair placed in front of it. There was also a second monitor connected to the computer that mirrored the screen from the one in front of the participant so the activity on the computer could be monitored by the researchers. This monitor along with the researchers was disconnected from the participants view by placing two folding screens along the middle of the room.

Figure 1: Demonstration of the research setting by one of the researchers.

When the participant first arrived, they were handed a printed consent form to read carefully and sign. They were then instructed to take a seat in the chair and the researchers went through the structure of the study with them, as well as told them they are free to stop their participation at any moment if they so wish. Data sensors connected to a NeXus-10 MKII (MindMedia) device were then attached, with ECG sensors being placed on both wrists (and ground on the left forearm), following the device's manual. GSR fingerbands were placed on the middle and ring fingers of the weaker hand. The participants were then handed a pair of Audio-Technica ATH-M50x headphones to wear and adjust to their liking, as well as a wireless Dualshock 4 (Sony) controller to hold. They were asked if they were comfortable and if so, the researchers booted up the game on the PC. The participants were told that they will be getting to play just one of three scenarios, but they were not told which one. They had freedom to get used to the controls and the game at their own pace and they were encouraged to ask any questions they might have during the tutorial section of the game. Data recording was started on the BioTrace+ software (MindMedia) at the same time as the tutorial started to establish a baseline measurement before moving on to the actual game. The lights were dimmed (but not turned off) in the room to help the participants focus on the game while still being able to see the buttons on the controller. When they felt ready, they were allowed to enter the game from the tutorial section. After completing the game, the lights were turned back to bright and the controller and headphones were given back to the researchers, who also removed the sensors. The participants were then asked to come to the other side of the screen for an interview. After the interview, they were thanked for their time and allowed to guess which one of the three scenarios they had gotten. If there was some time left over, they were also offered the possibility to try the other scenarios just for fun, as many of those in the neutral or the control groups did want to try the horror music condition as well.

3.2 Game design

A custom game was created for the study to control the variables and to facilitate easy in-game data collection. The key idea behind the game design was to have the atmosphere and the game mechanics be as emotionally unexciting and vague as possible, so that both the neutral and the horror music scenarios would fit the scene. A goal was for the game to afford for some strategy involving pathfinding, while not being too difficult to navigate and control. The game was designed to be playable with a controller, and not a keyboard and mouse setup, as it was thought to be easier for beginners to grasp. Similarly, the cognitive task in the game had to be simultaneously engaging, but easy enough to understand on the first playthrough. The duration of the gameplay session was also an important thing to consider, as too short of a session would make the HRV readings prone to error, and too long of a session could cause fatigue in the players and an excess of data for the scope of this study. The platform for developing the game was chosen to be Unity (Unity Technologies). So, with these ideas in mind, a game was created for the study. This section describes the game design first while overlooking the game audio, as it will be given its own chapter.

3.2.1 Main menu and tutorial

The game has three scenes: main menu, tutorial and the main game.

The main menu, operated by the researchers themselves, has buttons to start the game, edit the options and quit the application. In the options menu, one can set which research scenario will be played, as well as set the game language to English or Finnish. The controller is not activated until the tutorial level has started, so only the researchers were able to change the settings or start the game during the session.

The tutorial scene featured a series of five rooms, and each room has a game mechanic with instructions to try out. The tutorial section starts with a full screen image of the controller, showing the buttons and their respective actions needed to play the game. Once the screen is closed, the player starts in the first room where there is a simple door on the wall with instructions on how to open it. To reach the door they must first know how to move and turn the camera to face it. All the players were able to do this very easily. The next room features a small ledge, that the players were instructed to jump over. The third room has instructions on how to use the camera mechanic. There are three sets of instructions, with the first one showing how to open and close the camera view, the second explaining the main use of the mechanic, and the third one explaining the flaw detection mechanic and how to interpret the interface. The room also has four donut shaped objects, and two of those trigger the flaw detection on the camera. The player is encouraged to try the camera on those. The fourth room features a simple set of instructions on how to open and close the to-do list on the screen, and how to interpret its contents in-game. They are also given the option of pausing the game on their controllers. After this, they can move on to the last room and activate a cube there to start the game itself. This cube is used in the game as the starting point for the level, as well as a place to end the gameplay session when the game is completed. This was to ensure that every participant would already be familiar with using the object and no confusion would arise from ending the gameplay session. Once the player activates the cube, they are loaded into the main game, and the tutorial ends.

Figure 2: Screenshot showing instructions in the game tutorial.

3.2.2 Narrative and game mechanics

A narrative was written of the player character working for a housing company inspecting rental properties after the tenants have left. The game starts with a simple graphic where the player receives a text message from their boss, asking if they have the time to check one last location for the day. The player character has no choice but to accept the task they are given, and the game starts next to a cube in front of the house.

The main game mechanic is to move around the property and take photos of any flaws or damages within or around the house with an in-game camera. The camera works with a single button on the controller, and while in the camera view, the players' field of vision is limited to that of the camera lens. Whenever the camera is focused on a flaw, a graphic with three question marks pops up on the viewfinder to let the players know for certain they've found something. Once a correct photo is taken, a sound effect of a man humming affirmatively will play as well. They are told at the start of the level that there are eight possible flaws to be photographed, and there is a counter for flaws found on the upper left corner of the screen. This was to ensure the players would not get frustrated looking for nothing, and to, of course, keep track of their progress. The game also provides them with a general list of places and things to inspect within the level. It is possible to come across all of the hidden flaws by simply following the list. The task is a simple error detection task, but it still demands focus and attention from the players to complete while being mechanically simple and forcing the players to move around the level. Besides the main mechanics of movement, looking around, and taking photos, the players can also jump and walk up and down stairs. They can also open and close doors.

One aspect that was not thought of until after starting the experiment was that the concept of finding eight items in an area can be easily associated with the popular horror game and cultural piece *Slender: The Eight Pages* (Parsec Productions, 2012), a game which has been discussed by, for example, van Elferen (2016a). It is a game where you must gather eight notebook pages in a dark open area, with "Slenderman" hunting you down. The number of flaws was simply a coincidence, but still the fact that our main game mechanic was very similar to that of a hugely popular horror game is good to acknowledge and discuss.

3.2.3 Level design

The level is designed so that the player starts a short distance from the house by a cube with an instruction plaque placed on top. The house has two doors, one facing the front yard and one facing the backyard. The garage door is not interactable, but the garage itself is accessible from within the house. There is also a shed in the backyard, and a white fence surrounding the property. The fence cannot be jumped over. On the east side of the fence there is a flaw, where a section of it is broken down. The yard has some elevation changes to it, with it rising up from the house on all of the sides except the front. There is also an empty shed in the backyard that has no points of interest to it. The playing area is restricted by invisible walls, so the player will have no choice but to stay in the proximity of the house.

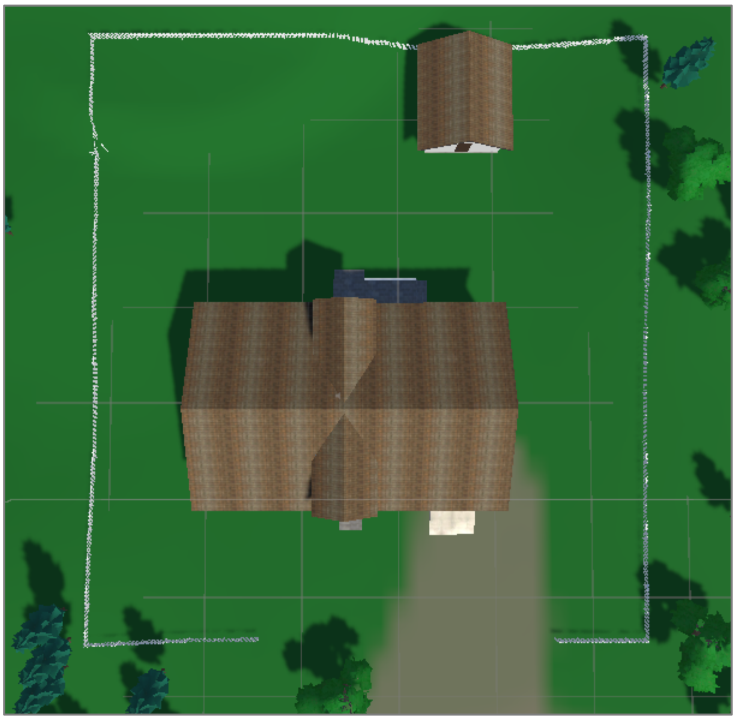

Figure 3: Top-down view of the map.

The house is nearly unfurnished aside from a few items that are left behind. This was a conscious choice to give the impression that the previous tenants had moved out. The first floor contains a small closet on the right next to the front door, with a staircase leading up to the second floor right next to it. On the same wall on the other side of the staircase, there is a door to the bathroom. The bathroom has a flaw on the back wall next to the bathtub, where there is some mold. The space opens up after it, to feature a furnished kitchen to the right, and an open empty living room space to the left. There are big windows with a view to the backyard from the kitchen and the living room. The back door is also located on the back wall opposite the front door. To the left side of the main entrance, there is an empty room as well with a window facing the front of the house, and a window facing the east side of the house. Behind the kitchen, there is a door that leads to some storage/utility room with cabinets and windows facing the west side. From here you can access the garage as well. The garage has small windows to the west side of the house, but they're so high up the player can only see the sky through them. The garage has two flaws: a graffiti tag on the wall, and some cracks on the concrete floor.

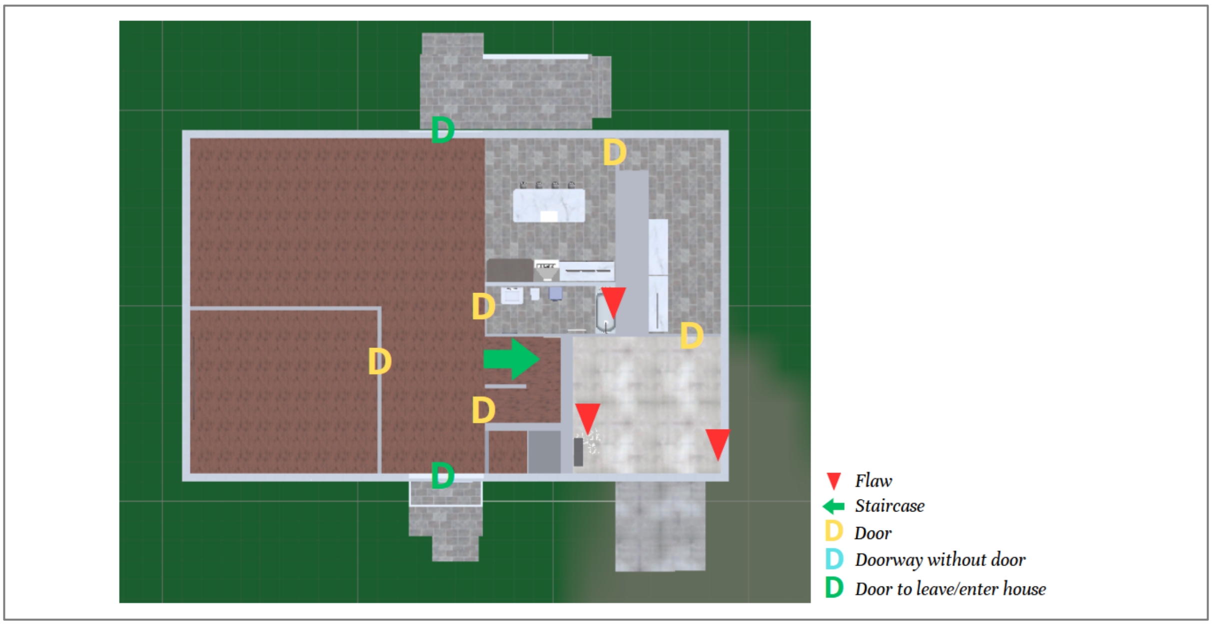

Figure 4: House first floor map.

The second floor has two large windows on the front and the back side of the house. The window facing the front yard has a balcony behind it, and a doorknob to what appears to be a sliding window screen, but it is not interactable. The east side of the floor features two bedrooms. The bedroom closest to the staircase has a wardrobe but it is not interactable. The other bedroom has a single cupboard. This bedroom has three flaws: the door to the other bedroom is broken and has fallen down, the wallpaper behind the cupboard looks like it has been ripped off, and the curtain rod on top of the window has fallen off the other end. They both have a single window facing east and both have curtain rods on top of the windows. The rest of the floor consists of an open space with a fireplace and a bookshelf. The space has a large window almost the size of the wall facing east, and finally there is a door to a storage room on the same wall as the fireplace. The storage room has small windows facing the east, but much like the garage they are too high up to show anything but sky. The room has two metal shelves for storage, and there is a flaw in the form of some mold visible on the wall behind the metal shelf.

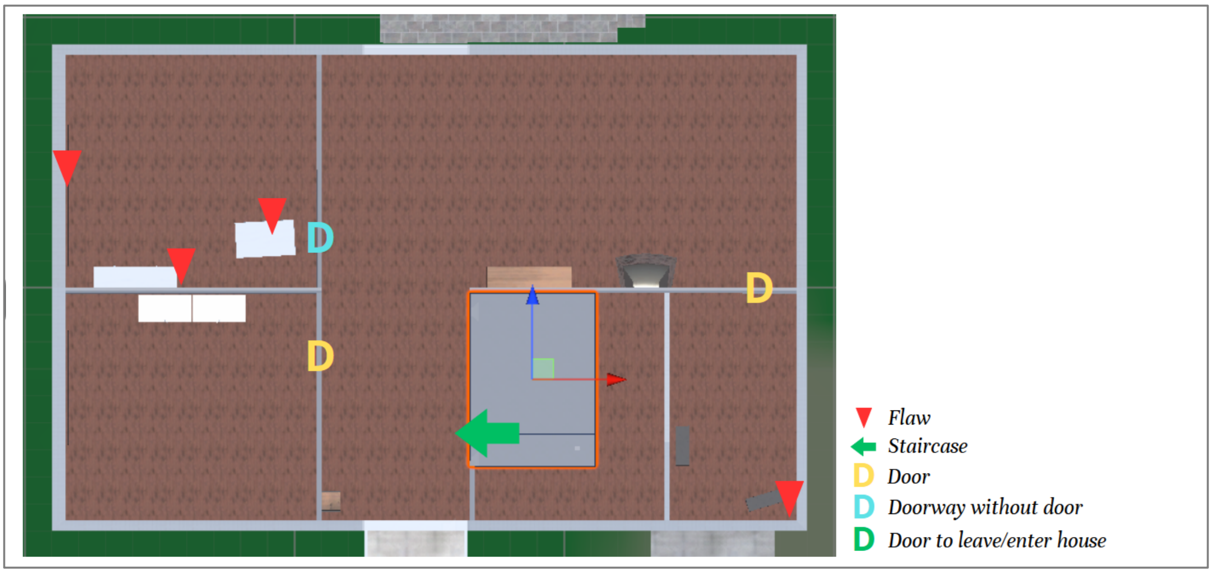

Figure 5: House second floor map.

Flaw placement is key in how the gameplay loop shapes up to be. The house was to look nice on the surface, but after further inspection the flaws would start popping up. This meant that preferred areas for flaws were those that were further away from the main corridors and entrances for flaw placement. For example, half of the flaws were upstairs, which was thought to be the last place to check for most players. The garage also rewarded the players with two flaws, as you had to understand the access there was behind the kitchen because the main garage door did not open.

3.2.4 Graphics and visual design

The visual design is of course a major factor when considering the mood of a game, and in this case the aim was to create an environment that would not feature any strong stylistic or emotional connotations to reduce the number of conflicting variables in the game. That being said, neutrality is a choice in itself so the leading idea was to have something that could be interpreted differently depending on the musical stimuli, while not looking out of place for the music. Hence, the game could not have a stereotypical horror look with neutral pleasant audio, nor could it be a silly kids' game look with the horror audio. In the end it was decided to go for a kind of a game level demo look, with realistic proportions and environment to navigate, but with the textures and most items being very simple. The demo look was achieved by creating the level almost completely using the Unity ProBuilder package, and no detailed custom assets were created. ProBuilder is an easy-to-use tool that allows for building, editing, and texturing custom geometry within Unity, and it is commonly used for level-editing, playtesting, and prototyping among other things. For the furniture, trees, and other items that needed more detail than what ProBuilder could provide, freely downloadable and popular assets from the Unity Asset Store were used. So, essentially the game looks like what could be an asset flip demo for an actual game to be created. This fitted well with the study being marketed as one testing the gameplay skills of the participants. The idea of the game being an experimental device and not a game in the traditional sense supported the demoish look as well. Still, one concern with the look was that it might disrupt the immersive experience required from the game, and the answer to this question regarding the immersiveness of the stimulus is addressed in the results section later on.

Figure 6: Screen capture of a view from the second floor, showing the lighting and wall textures.

The house in the game looks rather new, and the surface texture choices were made to reflect that. The outside walls are bright white, and the interior walls are a softer shade of white. The ceilings are a white wood texture, and the floors are mostly dark wood. The kitchen, the utility room, and the bathroom have tile floors, and the garage floor texture is concrete.

The lighting for this game features a cloudy sky, with a corresponding lighting coloration. The sun shines down from the front-east side of the house, making its shadows land on the back-west side. The shadows are rendered on the inside of the house as well. All of the windows have a reflecting glass material to them. The outside windows reflect more, which makes it harder (although still possible) to see inside, while from the inside it is easier to see out.

The user interface is also very simple and done using Unity's stock features. HUD (from the aviation term heads up display) refers to the game-relevant information that is in real time relayed to the player during gameplay. This might be in some cases something like a heath bar, an ammunition counter, or a mini map. Our game featured a flaw counter on the upper left corner of the screen, and a timer counting down from fifteen minutes in the top middle of the screen. There were also button indicators in both bottom corners of the screen, that indicated controls or actions that were available.

The house inspector's to-do –list is a simple grey box you can open and close by pressing the L1 button on the controller. It contains text listing the different places for the player to inspect.

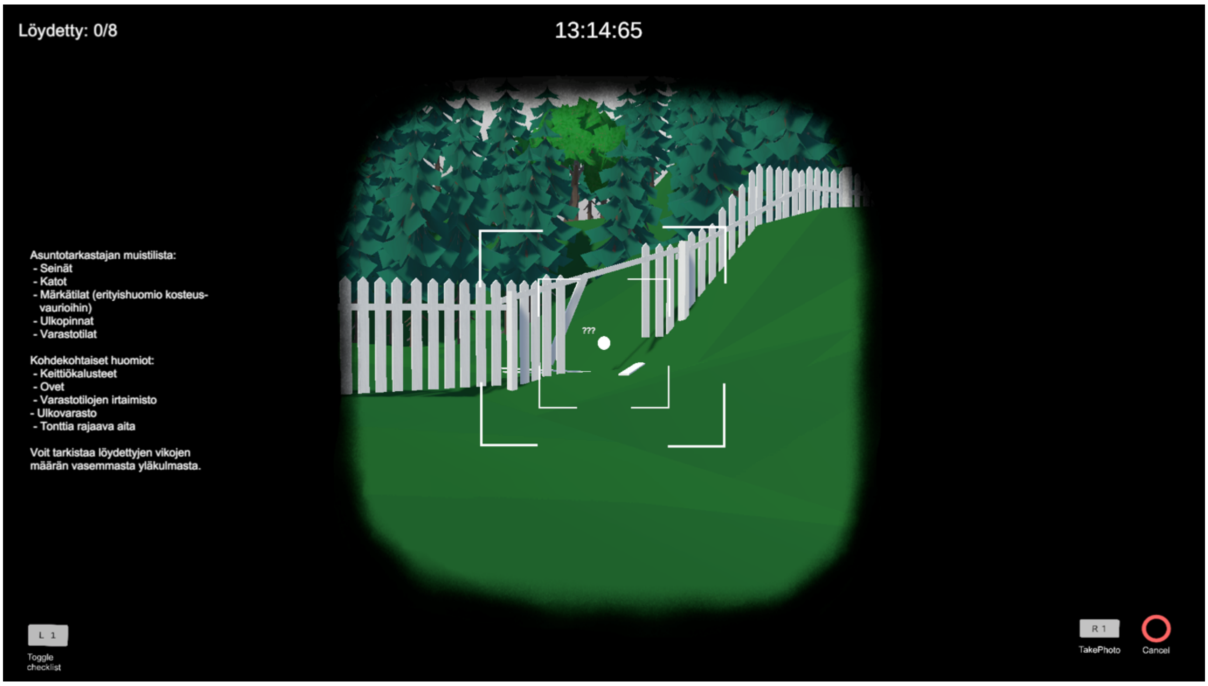

Figure 7: Screen capture showing camera view of a "flaw" in the fence.

The camera view was created by placing a dark vignette on the screen, with a clear spot in the middle for the camera viewfinder graphics. Once a photo is taken, the vignette disappears, and the picture shows up in a polaroid to the center of the screen. There is a quick fade-in animation that resembles the development of a traditional polaroid photo. This view can then be closed.

All text items done through Unity itself are using the default font of the engine. Some graphical items like the camera interface, and the tutorial instructions were done externally in Microsoft's Paint 3D, and they are graphically very simple. The graphic where the player receives a text from their boss was done in Adobe Express.

3.3 Music and sound design

3.3.1 Overview

Horror games such as *Amnesia: The Dark Descent*, The *Silent Hill* series (Konami, 1999–), *SOMA* (Frictional Games, 2015) and *Dead Space 2* have been discussed for their music and sound design by many (e.g., Van Elferen, 2016a; Sweeney, 2016; Bridgett, 2017; Whalen, 2007), and alongside past literature, these games worked as a source of inspiration in creating the music for this game as well. The music is fundamentally based on the idea of layering, as the beneficial or even essential nature of layering and dynamic for highly immersive games has been discussed in previous literature (e.g., Medina-Gray, 2016; Bessell, 2018). These layers consist of musical loops as well as single-play triggers, which both can be considered as musical modules interacting together with the player as well as reacting to overall game progression. As discussed earlier, dynamic music accomplished by layers and carefully considered transitions was a key element in the music. Stevens' (2021) approach of utilizing ambiguity and harmonic stasis seemed like a natural choice of execution in this case. As ambient and modular music is not exclusive to horror games, but for many other genres as well, this method of production fit the neutral scenario's composition as well, and by following this method in both productions the risk of influencing results by technical and productional differences was avoided. It is good to bear in mind that in this case, due to the short length of the game, the creation of the music was significantly easier to tackle in comparison to games with hundreds of hours of content – which inherently brings forward a plethora of additional challenges, such as technical limitations.

The following chapter will go over the composition and production of each scenario.

3.3.2 Production

The music is designed so that every layer and trigger can start at any random point throughout the game without the overall soundscape getting disturbed or cluttered in an undesirable manner. This is ensured by not following time signatures and having loose expression, typical to ambient music (Berndt, 2019), as well as leaning on rather atonal cohesion. Multi-track segments were joined and bounced out as single tracks for final implementation to the game. This also reduced the overall workload of implementation without compromising quality or important features of the audio. The tracks were exported as 44,1kHz mp3-files. A total of eight individual tracks were exported per scenario (anxious and neutral). This method supports the idea of "dynamic mixing", with musical segments starting and ending without being tied to other musical layers, ensuring that the start or end of a single segment does not disrupt the overall ongoing mix (Berndt, 2019).

The music was created using Logic Pro (Apple Inc.) digital audio workstation and listened to in production through Audio-Technica's ATH-M50x headphones which is the same model as the participants used during the gameplay session. The Minilab 3 MIDI controller from Arturia was used for creating musical sequences as well as for editing and automation, such as volume automation and panning. Several libraries from Logic, Spitfire Audio, Arturia and Native Instruments were used to pick and edit sounds and samples. Some sounds were heavily edited in character whereas others were used in their original form. Plug-in effects such as Space Designer (Logic), Phasis (Native Instruments) and VocalSynth (iZotope) were implemented in various ways to achieve several goals, such as creating dimension, dissonance, and distortion.

Sound effects and environmental sounds were created by using samples from Adobe Audition audio libraries, with added plug-in effects such as reverb and volume control to achieve the desired character and "natural" placement in the mix. These elements include, for example, multiple walking sounds (wood floor, stone floor, grass, gravel), door opening and closing sounds, outside ambience and interior ambience. Camera sounds (focus, shutter) and the main characters' sound cue ("mhmm" sound that is played when a flaw is detected and photographed) were recorded using a RØDE NT1-A condenser microphone and Focusrite Scarlett 2i2 sound card, and lightly edited in volume and reverb in Logic.

The aim was to give the player a sense of being "inside" the game, using music and sound to interpret the story and the environment as well as being alert and aware of "moving" sounds and the locations of different sound sources scattered around the house. The player would hear sounds from behind, left, right and front, to bring out a sense of danger as well as being in a 3D audio environment. In many games, the direction of the sound can help the player navigate in the game's world, as well as help them assess the level of danger. In the anxious scenario, direction and placement were also aimed to throw the player off guard and confuse them to create anxiety instead of preparing them, for example, to fight enemies. Whereas *Dead Space* is a great example of a game that provides the player with navigational and strategic tools via music (van Elferen, 2016a), this game focused more on the *Amnesia* approach, as the player could not run or have weapons, and the frantic audio would ideally strengthen this acknowledgement. The technical approach to this was to carefully execute the placement of different sounds into the mix, their distance to the player, the angle of their placement, as well as their reverberation and space design. Panning, phasing, stereo spread and stereo split mechanisms were used to achieve these effects, as well as plugin effects for reverb, echo, and so on. Some tracks include, for example, ear-to-ear panning and sweeping movements from back to front, achieved by automation programming executed with the Arturia Minilab 3. The walking sounds and the heartbeat sounds were kept in the middle of the mix to simulate a natural audio environment.

In the neutral scenario, these effects were also implemented, but in a different manner, focusing mostly on creating a light, peaceful ambience.

3.3.3 Composition

Both the anxiety-inducing music and the neutral music share the principle of having a base loop, a low-focus drone that is quite subtle and not inherently specific to any certain mood. In both scenarios, the base loop is audible throughout the whole experiment as an element that helps seamlessly bind together the game's environment, sound design and rest of the music – while also acting as a concealing element, hiding the points where musical sections stop and start over again. Ideally, the combination of music and sound design can strengthen player immersion significantly (Medina-Gray, 2021). The continuous base loops are in both musical scenarios accompanied by musical triggers that are tied to the players' in-game actions (taking a photo), in an effort to strengthen immersion and level of interaction (Calleja, 2011). As stated by Kaae (2017), the music appears linear to the player (p. 78), but the multiple modules are programmed to interact with each other in a random manner.

In the neutral scenario, a clutter of sounds is more diminished, and the sound design comes across as clearer and airier. The music includes a wide range of dynamic quality, with compression left to minimal – some parts are quite quiet, offering room for growth and crescendo, with the loudest parts controlled with limiters. In the final stage of the music creation, a plethora of sounds and musical segments were discarded to avoid over-cluttering the auditory environment.

Figure 8: The waveform of layers and triggers being added in a linear form (anxious scene). The markers on the top of the image indicate the start of each segment.

Although the attempt was to create music that would not be easily predictable, cliche-sounding and this way annoying to the player, it also had to include some familiarity and predictability for it to be able to convey messages and emotional cues as well as set the overall mood for the game in the player's mind. This was necessary for a player's interpretation and assessment of the environment they have entered, and it is a key element in media such as movies as well as games. The player constantly interprets the music, and as van Elferen (2016a) states, it is unlikely that a person watching a horror movie would interpret a low cello motif to indicate that the protagonist is likely a classical musician (p. 36). Instead, the viewer would likely interpret the protagonist to be in danger. This kind of audio-visual literacy is necessary for emotionally impactful pieces of media, which means that the audio had to be created bearing this in mind.

See attachments 2 and 3 for technical specifications of each layer and trigger.

3.3.4 Scenario 1: Anxious music

The anxious scenario opens with an airy and slightly dissonant base loop that consists of long repeating notes accompanied by textural piano key swarms and tape ambience. The sound is a mix between a synth/strings drone instruments with added piano textures. The atmosphere is ambient and stagnant, creating a sense of anticipation and having lots of room for growth. The sonic environment at this point is rather low in volume, leaving room for sound effects such as walking and nature ambience, but also allowing the player's imagination to fly in terms of expectations and interpretation, as well as for the anticipation of a sudden or loud sound, as Bridgett (2017) lists as a key element of survival horror game audio (p. 130). Low pitch, slow or moderate tempo, low sound level and soft timbre have been found typical to music that anxious music (Trevor et al., 2023, p. 385).

The audio director of *Dead Space,* Don Veca, says that the game has an airy, ambient base drone, which then, when an enemy approaches, allows a sonic build-up to form for the music to morph into fight scene music (van Elferen, 2016a). It was decided to have this kind of ambient start as well in order to execute such sonic build-up as well in our game. A second looping layer is presented on top of the first loop after 65 seconds of gameplay. It is a breathy, flute-like drone instrument with added glimmer, and it sounds "glitchy" at times, achieved by adding a Step FX (Logic) plugin on the track. The tuning of the track moves slowly and slightly up and down, creating dissonance. The sound is played higher than the first loop, making it fit naturally into the mix. A third layer is added after 120 seconds of gameplay, and it presents a slightly choppy, yet airy synth resembling a piano, played at a high range, yet sounding discrete. It is panned slightly to the right with a value of +4.

A fourth layer is added after 300 seconds of gameplay, consisting of a heavily modified synth instrument that resembles a combination of a swarm of bees and a humanoid, achieved with multiple effects like the VocalSynth (iZotope) plugin. The sound is accompanied by a rather beautiful-sounding dulcimer texture which follows the humanoid melody. The melody is melancholic, desperate-sounding and hinting towards impending doom. The combination of the swarm-of-bugs sound and (almost) human-sounding qualities alongside the rather beautiful dulcimer bring out a contrast between the familiar and the unknown, with the pleasant sound clashing with chaotic and distraught sounds, aimed to bring out a sense of despair, pending doom, and helplessness. This kind of blend between the pleasant (yet melancholic) harmonies and sonic features alongside the unpleasant, artificial and eerie features have been utilized in, for example, *Dead Space 2* (van Elferen, 2016a; Sweeney, 2016). The almost-human, or perhaps humanoid-sounding "wailing" that "sings" the desperate and longing melody together with the dulcimer was aimed to create a feeling of loss, perhaps because the protagonist would soon unveil a horrifying event that took place in the house. The unsettling and disturbing qualities of this trigger are presented to the player as an indication that something horrific might have happened, and if it did, it was likely not for natural causes and the protagonist is not safe wandering around the scene. In *The Last of Us* as well as *Silent Hill 4*, intensely sad musical elements are often present, ideally making the player more attached to the story and its characters, while also getting uncomfortable due to the sad music and imminent horror. This layer also features ear-to-ear panning and volume automation programmed with the Minilab 3.

In addition to the four looping layers, there are four single-play triggers, each lasting around 30 seconds to a minute. The first trigger, tied to flaw 2, was named "siren", since it leans heavily on the air siren resembling qualities, achieved by programming pitch-bend waves as well as volume automation on a dark, modulated drone instrument using the Minilab 3. The drone is accompanied by another drone, which somewhat resembles an emergency beep sound from national emergency notices presented via television; it could also be described sounding like ringing ears. This drone also features automation. The second trigger, tied to flaw 4, is not a musical segment, but instead a sound effect, designed to catch the player's attention and throw them off guard. The sound resembles something heavy being dragged accross the wooden floor, and it is placed in the middle of the mix without any visual representation of the sound source present.

The third trigger, tied to flaw 6, was named "pressure pulse", and it is the loudest in volume and dynamically most wide; it features a choppy, machine-like pulsating instrument accompanied with intense sub-bass hits as well as heavy and low growling-like instrument – and finally, a heartbeat sound. The final trigger, tied to flaw 7, was named "saw", and it consists of a heavy and distorted bass, repeating a slow, low pulsing motion, which was automated to vary in pitch bend, volume and expression, programmed with the Minilab 3. The bass track is accompanied by a low and heavy rumbling sound, amplifying the ominous feeling of the trigger, also automated volume- and expression-wise with the Minilab 3.

One additional trigger was created but was left out of the final game. It was named "anxious drone" because of its low, heavy and far-away sounding drone base, accompanied by speech-resembling and whispery "demon chatter", which moves from ear to ear with varying dynamics. The drone includes some pitch bend, although not as extreme as the siren trigger did, but just enough to bring out dissonance and uncertainty due to the wavy tuning. However, the "demon chatter" sound could perhaps have been almost a 'too' concrete suggestion of the presence of a supernatural entity, which might have overpowered other auditive elements. Otherwise, the dismissed trigger was built using similar elements to those that were already presented in other segments, such as a low drone and pitch bend.

Figure 9: Pitch bend automation on the siren track.

An anxious effect was sought for with careful consideration for the sound of different instruments as well as leaving the music mostly unresolved, leading to an unsettling atmosphere (van Geelen, 2017). The previously discussed sanity system of *Amnesia: The Dark Descent* was one source of inspiration for this production. Many of its sonic features, such as crescendos, glissandos, (reverse) echo, whispers, and heartbeat sounds can be found in this design as well. Trevor et al.'s (2023) article about anxious movie music acted as a great additional source of material for mapping out some of the qualities of the music, as movie music and game music naturally share a lot of common ground.

The human-resembling, monstrous sounds were created with van Elferen's article *Sonic Monstrosity* (2016b) used as a source. She describes a scene from *Silent Hill* where pounding drones, noise and monstrous sounds from an unseen source alert the player of impending danger and ill intentions of an approaching creature (2016b, p. 2). Whalen (2007) refers to the same scene, describing its sonic qualities: "...unsettling blend of wind, air raid sirens, machine-like chugging, indeterminate groaning and infrequent instrumentation such as strings or organ", explaining that the smooth blend of these sounds is made possible due to the gradually added individual layers (p. 77). Van Geelen (2017) also mentioned an ambient base layer in *Tomb Raider Legend* (Eidos Interactive, 2006), on top of which a layer of electric guitar is added when encountering enemies (Van Geelen, 2017, p. 96). In this case, a single trigger would contain multiple audio tracks, from 2–4 per trigger, to keep them cohesive and heighten each sound's unsettling effects. Sound cues such as demon-like chatter, siren sounds and screeches were tied to musical segments as additional elements to throw the player off guard, as discussed also by many others along van Elferen and Whalen (see for example Bridgett, 2021; Grimshaw, 2021; Medina-Gray, 2021). Cues such as these were aimed to convey a meaning to the player in a “non-natural” way; as a “natural” auditory cue might be something like hearing a door open when opening it, these cues were presented without direct relation to a visible object in the game world. Digital effects such as reverse delay and phasing were used to distort the sonic environment, as done often in horror films and games such as *Dead Space 2* (van Elferen, 2016a). A heartbeat sound was added to create a sense of danger and urgency, as well as making the player aware of their character being in a heightened and disorganized state, as well as being themselves a sound source audible to possible enemies, as done in games such as *Amnesia: The Dark Descent* and *Slender: The Eight Pages* (van Elferen, 2016a). The heartbeat effect is only heard once for approximately 30 seconds throughout the whole game to strengthen the emotional effect of the trigger it is tied to; this trigger (“pressure pulse”) can be considered as the climax of the music, being the loudest in volume due to a heavy crescendo, accompanied by a heavy sub-bass pounding and chaotic machine-like sound that goes back and forth in terms of volume dynamics in a “saw-like” motion. Multiple participants mentioned getting alert by this trigger and mentioned interpreting the heartbeat sound as a warning of imminent danger.

3.3.5 Scenario 2: Neutral/positive music

The neutral scenario offers a loose and airy soundscape with warm and glimmering tones. It opens with a breathy, slow drone, changing between major chords presented at a mid-range. The layer includes slight, ear-to-ear panning automation programmed with Minilab 3. Similar to the anxious scenario, a second layer is added after 65 seconds of gameplay. The second layer introduces filtered sweeping sounds which complement layer one harmonically, again in a slow manner, while also sounding somewhat distant in the mix. It is mildly panned to the left ear, with a value of 10. While the anxious scenario includes four layers and four triggers, the neutral scenario has three layers and four triggers. The third layer is identical to the one that is heard in the anxious scenario, adding an airy, discrete touch to the mix. The first trigger, tied to flaw 2, is a clean, bell-resembling musical segment, consisting of short, high-range notes. It is panned right with a value of +14. The second trigger, tied to flaw 3, is a muted piano segment, consisting of calm, major chords, and has a moderate amount of space reverberation. The third trigger, tied to flaw 5, is a pulsing synth mixed with strings. It is panned left with a value of –9 and has volume automation programmed with the Minilab 3. The pulsing effect is reached by adding a Step FX plugin with a syncopated pulse effect. The fourth trigger, tied to flaw 7, is a clean guitar segment consisting of an arpeggio swarm, sounding calm, airy and distant, with ear-to-ear panning programmed with the Minilab 3 and with added space reverberation.

3.3.6 Scenario 3: Control group

In the control scenario, no music is present throughout the game, but otherwise the soundscape is identical to the other two scenarios. For example, footsteps, door sounds, and environmental sounds can be heard throughout the game. However, the dragging sound from the anxious scenario was not included in the control scenario, nor were there any player-activated triggers present throughout the whole scenario.

3.3.7 Programming the audio

The audio was split conceptually into two areas: sound effects and music. The technical implementation is important to discuss because the soundscape is essentially performed by the game engine through code. The musical experience emerges from the interaction between the player and the game (e.g., Calleja, 2011), and this interaction is mediated on the game side by the game logic and code. Code of course is great for consistency, because everything it does has to be explicitly defined beforehand. This means that while the player can change the way they approach the game, the researchers can easily standardize the way the game responds to the player.

Many of the sound effects are tied to specific actions within the game, and thus they were implemented together with those elements in code as well. Unity runs game logic using C# scripts, and for example the door opening animation had a logic to it that as it played the respective animations that made the door either open or close, it also played the respective audio clips for door opening and door closing. All the door elements share the same behavior. The code was written so that each door could be assigned the sound clips separately by simply dragging and dropping the audio clips to the object in the inspector view. This made it possible to have different audio clips for the outside doors and the interior doors. The sound effects did not vary between scenarios. A similar script was done for the camera sound effects under the C# scripts that were tied to the camera and the humming sound related to the flaw detection logic.

There were two adaptive systems for sound effects as well: the footstep sound manager and the ambience manager. The ambience manager simply used a trigger box to determine whether the player was in the house or outside and played the corresponding ambience loop that fit the environment. The footstep sound manager used a raycast-mechanic to determine the texture that the player character was walking on. The code allowed the footstep sounds to then be tied to those textures, and if the player was moving while simultaneously being on the ground, the sound effect for walking on that specific texture was played. "Realism" was added by the code allowing for eight different footstep sounds in an array to be added per surface. It then used randomization to determine which of those eight sounds for that surface would play one at a time, at a comfortable interval. The volume of the sound effects was also randomized in the same way.

The music is layer based, and fittingly the system managing the layers was called "the music layer manager". The music's progression is tied to the player's progress in the game, following the idea of adaptive audio here as well. The loop itself consists of four layers, and the base loop is programmed to start at the beginning of the level. The three additional layers are then added on top of the base layer at intervals of 65 seconds, 120 seconds, and 300 seconds. The loops would play the same regardless of player progression. There are also audio triggers, that are tied into the player progression. The code constantly monitors the variable storing the number of flaws that the player has found, and the triggers are assigned to play when a certain number of flaws had been found, with the first one triggering at two flaws, second one triggering at four flaws and fourth and fifth triggers at six and seven flaws respectively. This was convenient because the game is not linear in its progression, meaning that the flaws could be found in any order. This way it was possible to simply track the flaw counter, to know which trigger had played at which point. This solution also made it so that the order of the triggers also stayed the same for each playthrough. The same behavior was applied for all three scenarios, but the loops were switched from "horror", to "neutral" or removed altogether. Since all of the scenarios use the same code, it was possible to inspect the difference in player reactions connected to the difference between the two types of music (and one type of musiclessness), as opposed to the difference between entire gameplay sessions with different musical placement.

An obvious problem with a trigger system tied to specific flaws would have been that the combination of layers would have been tied to the order where the player had found the flaws. Then again with the chosen implementation, it was not possible to control the location in the game where the player would hear a certain trigger, so for example if one happened to start outside the house, they would find the last flaw inside, playing the last trigger while in the house as well. On the other hand, if they found all the flaws inside the house first, they would experience the full soundscape outside of the house. These are very different situations, and the difference here could be a point of interest for further study. This approach was also necessary, because a linear game would not have allowed for the differences in gameplay strategies that was one of the key interests for the study.

3.4 Data collection

3.4.1 GSR data

Galvanic skin response (GSR) was one of the two physiological measurements collected from each participant. GSR data was collected using the Nexus-10 MKII (MindMedia) device and BioTrace+ (MindMedia) software. Two Ag-AgCL electrodes were attached to the middle and ring finger of the participant's weaker arm using finger bands from the Nexus device accessories. The cords were secured with medical tape to prevent pulling or loosening, and the participants were asked to avoid excessive movement. The GSR data was sampled at 32Hz. The data for each session was exported from BioTrace+ as individual tab-separated text files. The data was then imported to Matlab (MathWorks) software and opened for further inspection and analysis using the Ledalab (Benedek) toolbox.

First, a manual inspection was conducted to detect possible, clear artifacts. Then, a batch analysis for the data was conducted using Ledalab. The analysis method of choice was Continuous Decomposition Analysis (CDA) (Benedek & Kaernbach, 2010). For each individual data file, a butterworth low-pass filter was added with the lower cutoff frequency of 5, and the data was optimized using a default optimization tool on Ledalab. The data was separated into tonic and phasic components as part of the batch analysis. The results were exported into Matlab files for further inspection.

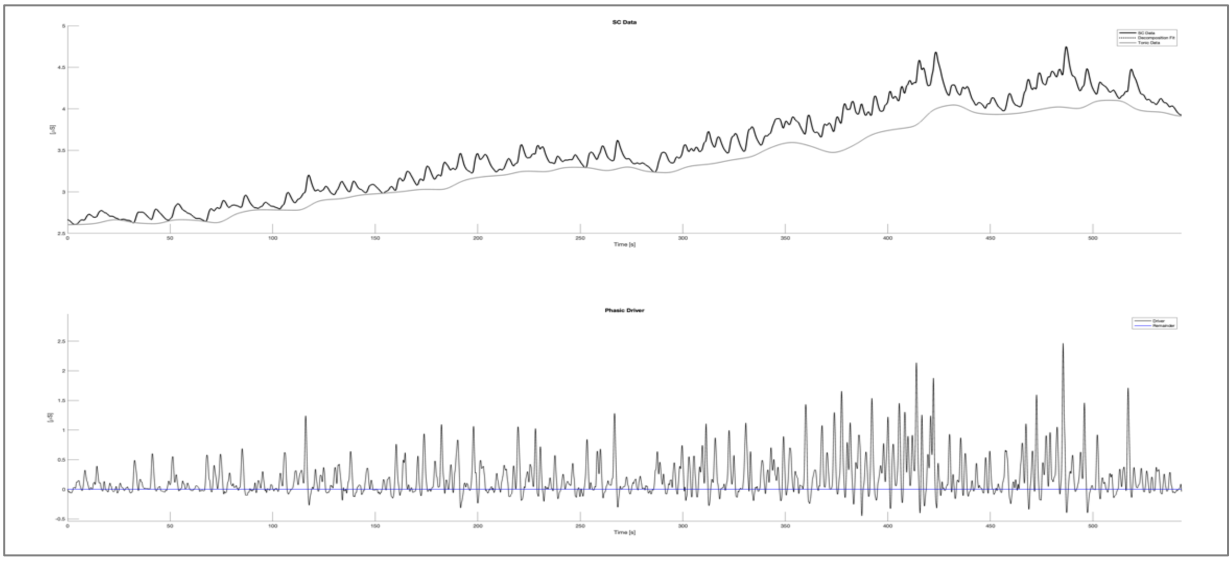

Figure 10: GSR data, collected during gameplay from a participant in group A, is split into tonic data and phasic data using Ledalab.

3.4.2 HRV data

For each participant, ECG data was recorded using the Nexus-10 MKII device and BioTrace+ interface. The data was collected using two ExG sensors attached to both wrists, along with a ground cord that was attached to the left arm. The data was sampled at 256Hz. Raw ECG data for each session was exported from BioTrace+ as individual tab-separated text files. The data was then imported to Matlab and analyzed via HRVTool (Vollmer, 2019). A batch analysis was conducted using HRVTool's settings. HRVTool's default bach analysis script fit the researchers' requirements well, and no additional adjustments were added. Artifacts were filtered using HRVTool's default filter setting with the value of 20 (Vollmer, 2019). The results were exported into Matlab files for further analysis.

3.4.3 Gameplay data

The data collection was implemented by a script within the game. It recorded player movements in real time and wrote the player character's position into an array in real time at the interval of 2hz. Faster sample rates were tried, but the way this was implemented caused undesired performance issues. The slower sample rate's capabilities were tested out with a replay system, where the movement data was interpolated by code to form a smooth replay ghost of the player. This ghost was then played back in the game engine, and then visually analyzed to see how "right" the gameplay looked. This ghost in fact did show the movement paths and the strategies involved very well, although some fidelity in the finer movements was lost.

The exported data file contained:

- time stamps of the data points in seconds (s)
- player characters three-dimensional position within the game (x, y, z)
- orientation of the player character in the form of Euler angles (x°, y°, z°)
- Number of flaws found (integer between 0 and 8)
- Current scenario as an integer between 0 and 2 (0 = A, 1 = N, 2 = C)

The filetype was .csv.

3.4.4 Interviews

A short interview, approximately 5 minutes long, was conducted with each participant. During the interview, participants were asked to rate different aspects of the game on a scale of 1–10, after which they were asked to verbally describe their rating. The interview questions were:

1. How difficult was the game? (1-10)
    a. Why? (What about the game felt difficult? What felt easy?)

2. How scary was the game? (1-10)
    a. Why? (What was scary, what was not?)

3. How pleasant was the game? (1-10)
    a. Why? (What made it pleasant, what was unpleasant?)

4. How fun was the game? (1-10)
    a. Why? (What was or was not fun about the game?)

5. How would you rate the game on immersion? (1-10)
    a. Why? (What made you immerse yourself in the game? / What broke the immersion?)

6. Any other thoughts/comments about the game or overall experience?

The structure of the interview shares similarities with the Game Experiment Questionnaire (GEQ), which uses a numeral rating system to assess player experience in seven areas: immersion, flow, competence, positive and negative affect, tension, and challenge (IJsselsteijn et al., 2013). A chance to give additional comments was added to ensure that the interviewees would not leave out any relevant information even if they felt like it would not fit any particular category.

The interviews were recorded with a Zoom H2n handy recorder and transcribed into written form on Microsoft Word. The participants were asked not to share any personal information during the interview to maintain anonymity. After transcribing and anonymizing (voice) the interviews, the voice recordings were destroyed, and an Excel sheet was created to compare the numeral ratings given by the participants.

4 RESULTS

4.1 Subjective measures analysis

4.1.1 Difficulty

The average subjective rating for difficulty was 2.77 out of 10 (*SD* = 1.07), with all three groups giving similar ratings. The participants mentioned the game controls, the time limit, and the challenge of finding the flaws as some specific sources of difficulty. While some found the controls a difficulty, they were most commonly mentioned as being simple and easy. Most participants found the main game mechanic to be the most challenging part of the game, which was one of the design goals to begin with. The game was quite easy in general.

4.1.2 Scariness

The average rating for scariness was a lot higher in group A (*A* = 5.125, *SD* = 1.32) in comparison to group N (*A* = 2.875, *SD* = 1.93) and group C (*A* = 2, *SD* = 1). Four out of four participants in group A mentioned music as a reason for the overall scariness rating. Another popular reason that was mentioned in all groups was the expectation of something scary, for example, a monster or jump scare, and some of the participants said that this expectation felt likely due to the mention of the game having horror elements in the study notification which was mandatory for all participants to read. Feeling fearful or anxious of the 'unknown' was also something that came up throughout the interviews, as well as the heightened awareness of being alone (and a sound source). One participant in group C mentioned that the silence felt scary. In groups N and C, some participants stated that they were expecting a horror game, but quickly concluded that it wasn't a horror game, nor was anything scary coming. Two participants mentioned that the camera movement felt slow; one of them was in group A and mentioned that they wished that the movement was faster to be able to look behind them. Two participants, one in group A and one in group N, noticed that the game *Slender: The Eight Pages* has a similar core mechanic of finding eight things in an environment.

4.1.3 Pleasantness

The average subjective rating for pleasantness was 6.15 out of 10 (*SD* = 2.08), with all three groups giving similar average ratings. The participants in anxious and neutral scenarios mentioned the overall mood in the game was pleasant, and attributed this to music, sound design and graphics. Music was not obviously mentioned in the neutral scenario as being pleasant, but the atmospheric sound design in itself was seen as pleasant and fitting by two participants in the group. The controls and the lack of music (in the neutral scenario) were seen as sources of unpleasantness for some of the participants.

Some participants in the neutral and control scenarios found it pleasant when they came to the conclusion that nothing [scary] was going to happen. Two out of four participants in the anxious scenario mentioned the suspense of "something coming" as making the game in fact more pleasant. Four players mentioned the lack of depth graphically as taking away points from the pleasantness of the game and two thought that the game looked nice. The rest of the players did not mention the graphics specifically. One participant in the neutral condition found the combination of noticing the time limit too late and the difficulty of finding the flaws highly unpleasant, resulting in the single lowest pleasantness rating of 2. The next lowest pleasantness rating of 4 was given by two participants in the control scenario. The game was generally seen as mildly pleasant by all three groups.

4.1.4 Fun

The average rating for fun was higher in group A (*A* = 6.5, *SD* = 1.30) in comparison to group N (*A* = 4, *SD* = 1.63), and group C (*A* = 3.5, *SD* = 1.30). The task of finding and photographing flaws felt fun for some participants in all three groups, and the storyline being fun was also mentioned. One participant in group A mentioned *Amnesia* as a game they thought of during their gameplay experience. One participant from group A said, that without the "horror aspect" of the game, the experience would not have been as fun. Another participant in group A mentioned that the mood of the game felt fun to them, as they were wondering what might have happened in the house, as for example, one door had been kicked down and the outside fence was broken. Some participants said that nothing in the game felt particularly funny to them.

4.1.5 Immersion

The anxious scenario rated highest in terms of immersion with an average rating of 8 out of 10 (*SD* = 0.82). The neutral score averaged a point lower with 7 out of 10 *(SD* = 1.00*)* and the control scenario the lowest with 6.25 out of 10 *(SD* = 2.22*)*. Music and sound were mentioned as one of the main reasons for immersiveness, but one participant in the neutral group said that music in fact decreased their level of immersion, because the "calm" music was not in line with the feeling of rush that they felt due to the timer running out. The narrow storyline and slow camera movement were also mentioned to break immersion, but overall, the immersion rating was high. The story was also mentioned by one participant to increase immersion. Immersion was thought to both decrease and increase due to graphics. The research situation itself was also seen by three participants as promoting immersion by listening to the game through headphones and the room being only dimly lit. The game scored decently high in immersion in all three scenarios.

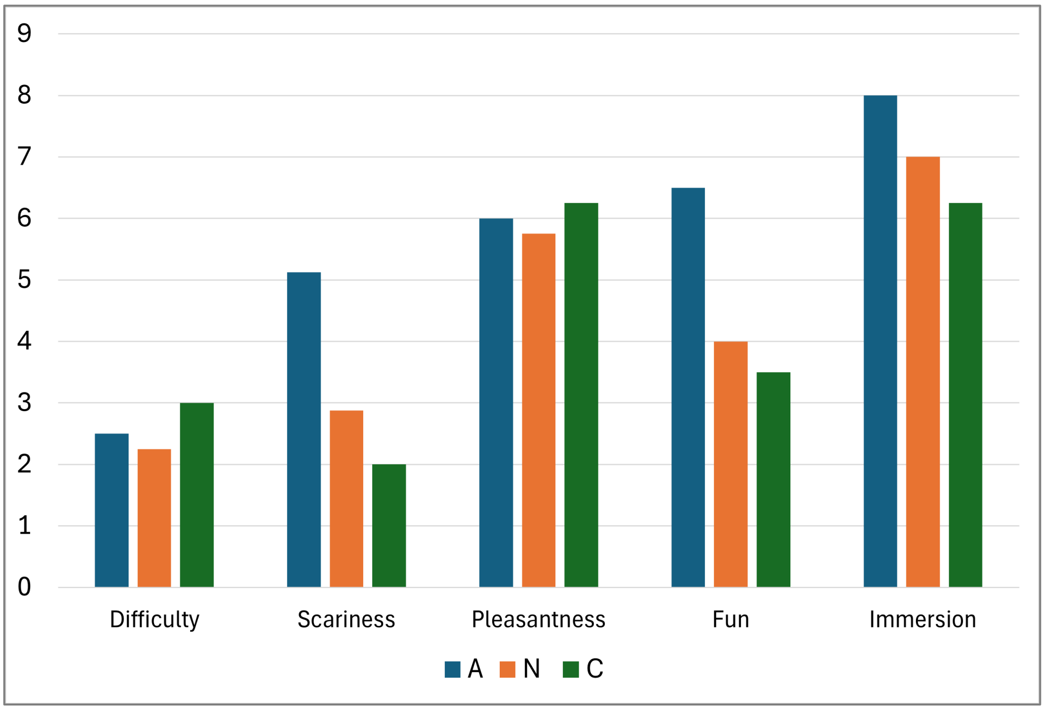

Figure 11: Showing the average subjective ratings for participants in each scenario.

4.2 Physiological measures analysis

4.2.1 Hypothesis 1

The HRV analysis also did not indicate significance throughout the whole analysis, which consisted of local rrHRV (p = .1032), SDNN (p = .2567), RMSSD (p = .3874) and HR (p = .5215) measures. Again, for each of these measures, the differences between mean baseline and mean gameplay segments were calculated, and the results were analyzed using ANOVA. The lack of significant values could have to do with the small sample sizes, yet any conclusion cannot be drawn without further research. However, based on the analysis it was noted that for all participants in group A, mean rrHRV (M = -0.9088, SD = 0.4194) values were lower during the gameplay segment in comparison to baseline, whereas for group N (M = -0.0313, SD = 0.5992) and control group (M = -0.3035, SD = 0.5335), it was found that some participants had higher and some lower values. One additional analysis method could have been utilized by connecting the events (taking a photo) to the phasic data curves to see event-related activity, yet this was left out of the analysis at this time. However, these findings seem interesting and indicate a need for further research.

4.2.2 Hypothesis 2

For the SCL data, the difference between mean baseline data and mean gameplay data of each participant was calculated, and an ANOVA analysis was conducted. The results of the ANOVA analysis showed that there was a significant difference between groups (F = 4.5708, p = .0427) and therefore a post-hoc test was conducted. The post-hoc method of choice was Dunnett's test, which indicated a presence of a significant difference (p = .0450) between group A (M = 0.5075, SD = 0.3286) and group C (M = 0.1235, SD = 0.1162), but not between group N (M = 0.1418, SD= 0.0418) and group C (p = .9882).

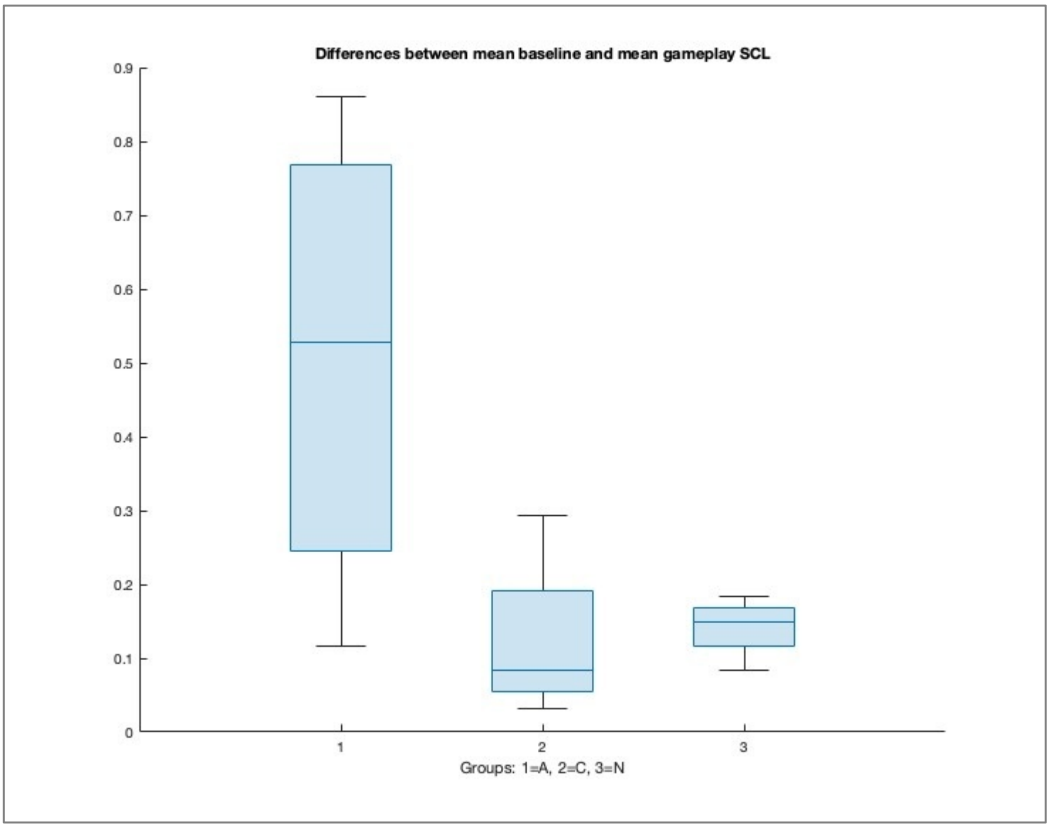

Figure 12: A group comparison of difference between baseline and gameplay SCL.

4.2.3 Hypothesis

From the phasic data, SCR's were calculated without baseline segment included after which an ANOVA analysis was conducted. No significant differences were found from the comparison between groups in terms of the total SCR peaks of each participant during gameplay ($F = 0.1607$, $p = .8539$). The differences from total baseline peaks to total gameplay peaks were also calculated, and an ANOVA analysis for this data did not find significant differences between groups either ($F = 0.3441$, $p = .7177$).

4.3 Game data analysis

One of the main points of interest for the study was to see if the players' emotional responses to horror game music were being reflected onto the gameplay. The movement data was visualized following the examples of Wallner and Kriglstein (2013) for an appropriate visualization. Being able to detect emotional responses from just gameplay data is an interesting prospect in itself but studying it can also give us an idea of the immersiveness of the game. Immersion has been conceptualized as "a feeling of virtual involvement" in a context where the user's actions are "actually translated into the gaming environment" (McGloin, Farrar, & Krcmar, 2013). In this case, if the gameplay behavior was congruent with the emotional response shown in the physiological data and the subjective appraisals, it could be deduced that the level of emotional involvement (Calleja, 2011) would have been high, and that the user's emotional experience also translated into the game environment indicating a higher level of kinaesthetic involvement as well. This would indicate a deeper level of immersion at least in these two aspects. Based on the results of the analysis of the physiological data, one should look for changes or anomalies in behavior that present themselves in the anxious scenario, but not in the neutral or control scenarios.

Gameplay data was recorded in the form of player character position, player camera angle, and game progress. Hypotheses were created based on previously studied cognitive and behavioral effects of anxiety as well as gameplay studies, and the data was processed and analyzed based on the needs of the question.

4.3.1 Hypothesis 4

It was hypothesized that players would more actively look for potential threats in the anxious scenario compared to the control and neutral scenarios. This is mostly based on Bateson, Brilot & Nettle's (2011) argument that preparing to detect and deal with threats is the function of the human anxious response on an evolutionary level (Bateson et al., 2011). Similar deductions can be made from the paper by Sylvers et al. (2011) where they define anxiety as a heightened state of vigilance in anticipation or response to a threat where danger is not clearly imminent (Sylvers et al., 2011). Eysenck and colleagues also found that anxiety would increase the possibility of getting distracted by increasing the significance of outside stimuli (Eysenck et al., 2007).

This kind of behavior could be detectable by looking at how much the players turned their camera during the gameplay session to scan their surroundings. The sum changes in Euler angles on the x° (vertical) and y° (horizontal) axes were calculated. The player had no control over the z axis camera movement. The angles were recorded in the form of direction at the time of sampling.

Degrees of rotation can be problematic in the sense that, for example, the values 5° and 365° are at the same position on a rotating axis. This was dealt with by running the values through a Matlab code that reduced the values to the distance from 0 *if* they were under 180°, and distance from 360° *if* they were over 180°, *or* over 360°. No values over 520° were in the data. The data for the x° and y° axes contained no negative values. The amount of change between each value was then calculated and negative values were turned into positive by taking the absolutes of each value. With this method, for example, the distance between 5° and 355°, would come up as 10°, as 5° would have been 5 values over 0° (+5) and 355° would have been five values under 360° (-5). If the values were then, for example, 170° (+170) and 190° (-170), this method would produce the wrong value of 340°. This was taken into consideration by taking all calculated values over 180°, and simply reducing them from 360°, to always get the shortest possible distance along the axis. The camera sensitivity was not high enough to move over 180° in 0,5 seconds (sample rate), so this should reliably give us realistic values. This gave us a sum amount of camera rotation for each participant on both x° and y° axes. The average speed of camera rotation per sample was calculated for each participant for both x° and y° axes by dividing the sum amount of camera rotation with the number of samples in the data file. The averages between scenarios were also calculated by taking the sum of the participants averages and dividing it by the number of participants per scenario for each scenario.

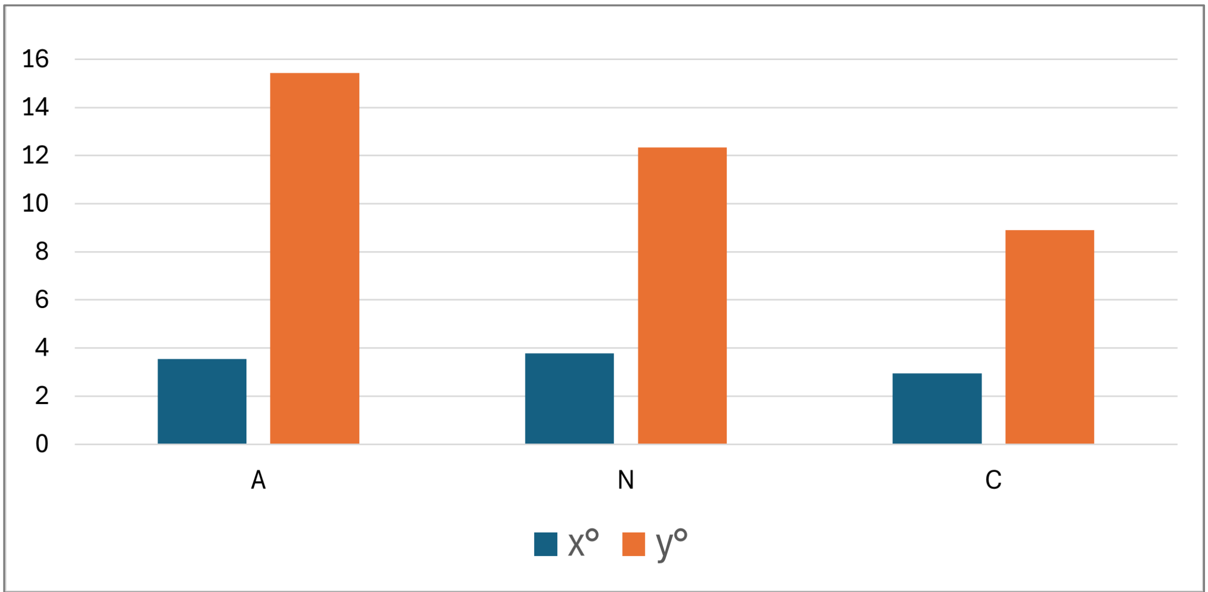

Figure 13: Mean camera movement along the x° and y° axis for each scenario.

In terms of x° axis movement speed, the anxious (*M* = 3.54, *SD* = 0.52), neutral (*M* = 3.78, *SD* = 0.88) or control (*M* = 2.95, *SD* = 0.51) scenarios did not significantly differ from each other, indicating no significant change in vertical camera movement between scenarios.

For the horizontal y° axis however, there is some separation in the values. The anxious scenario (*M* = 15.43, *SD* = 1.46) had the most y-axis camera movement compared to neutral (*M* = 12.35, *SD* = 4.23) and control (*M* = 8.90, *SD* =2.47) scenarios. The strength of the effect was tested by running a one-way ANOVA on the results, and a statistically significant effect was found ($F = 4.89$, $p = .036$). A post-hoc analysis was done using Dunnett’s test to compare the neutral and anxious groups against the control group, and it shows a strong effect for the anxious group ($p = 0.022$). The neutral group did not differ significantly ($p = 0.223$) from the control group. The difference in standard deviation is worth noting though, with the anxious scenario showing a significantly higher consistency compared to the population standard deviation (*SD* = 3.86). This is possibly due to both neutral and control scenarios featuring clear outliers (participants N2 and C10) in terms of y-axis camera movement specifically. This could be explained by the participants having less experience with traditional first-person controls on the gamepad, and participant N2 also mentions in the interview that the camera was the hardest thing to control for them. The effect from the ANOVA becomes more pronounced when removing these outliers from the data set (F = 17.26, p = 0.002).

More back-and-forth player character movement could also be indicative of this kind of behavior, where the players would be, for example, more hesitant to move to the next area instead of progressing faster and more confidently. The player position was plotted into a 3-d plot in Matlab, and different areas are highlighted below.

The resulting plots of these areas of interest for each scenario were simply visually analyzed, to see if any differences could be seen. In the following example of the plotted data for the players from the upstairs of the house, it can be seen that in the anxious scenario (A) the line is a lot more populated than in the neutral (A) or control (C) scenarios. This does seem to indicate more back-and forth movement in the anxious scenario compared to the neutral and control scenarios.

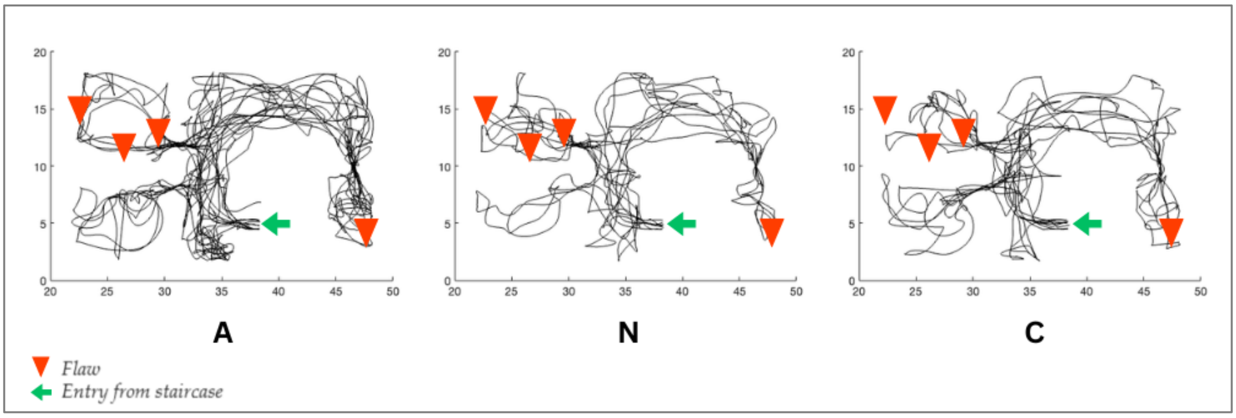

Figure 14: Movement data from the upstairs of the house for each scenario.

All of the scenarios produced similar movement paths, but some small differences can be found in places. In the upper left corner of the plot is a room with three flaws. The room featured most prominently three flaws, with the first being the room door that looks like it has fallen on the floor. The wallpaper behind the dresser also looks like it has been ripped off and the curtain rod has fallen down at one end. In the anxious scenario the players avoided the center of the room and moved along the walls, while in the neutral and control scenario the players walked more in the center of the room.

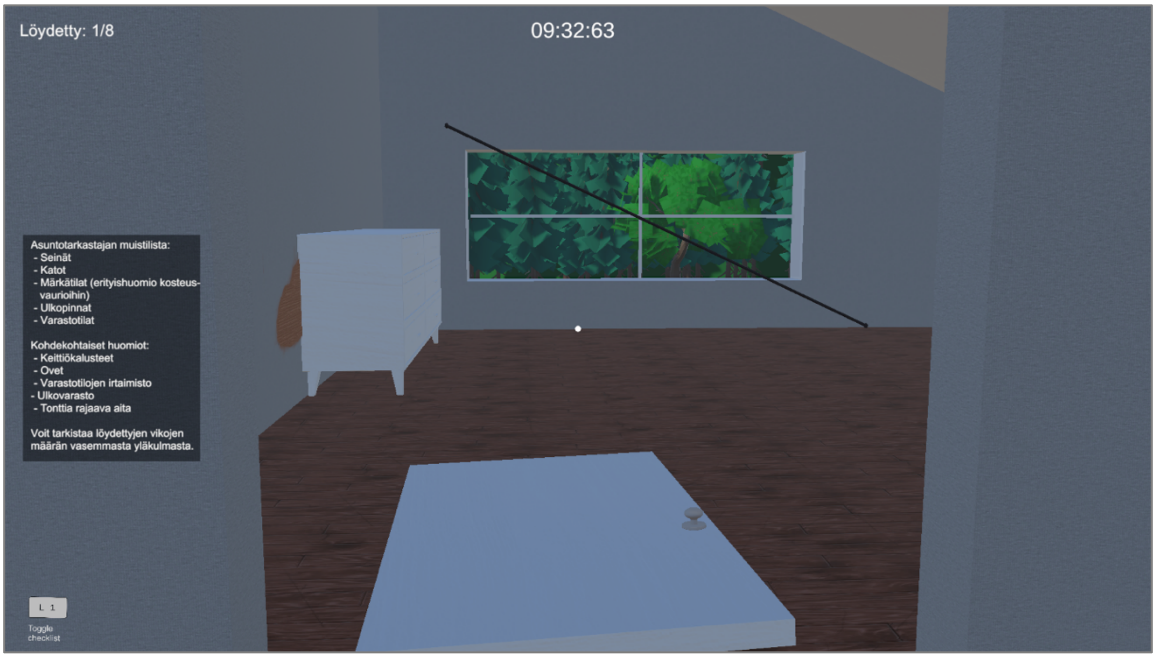

Figure 15: Screen capture looking into the room with three flaws.

A similar difference can be observed by eye in the graphs for the downstairs as well, where the anxious scenario shows a slightly denser plot compared to the neutral or the control group.

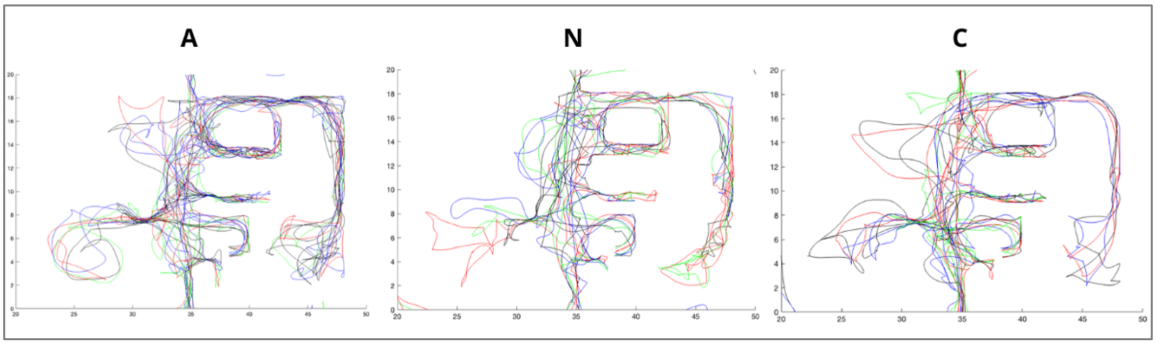

Figure 16: Interpolated movement data for the downstairs of the house for each scenario.

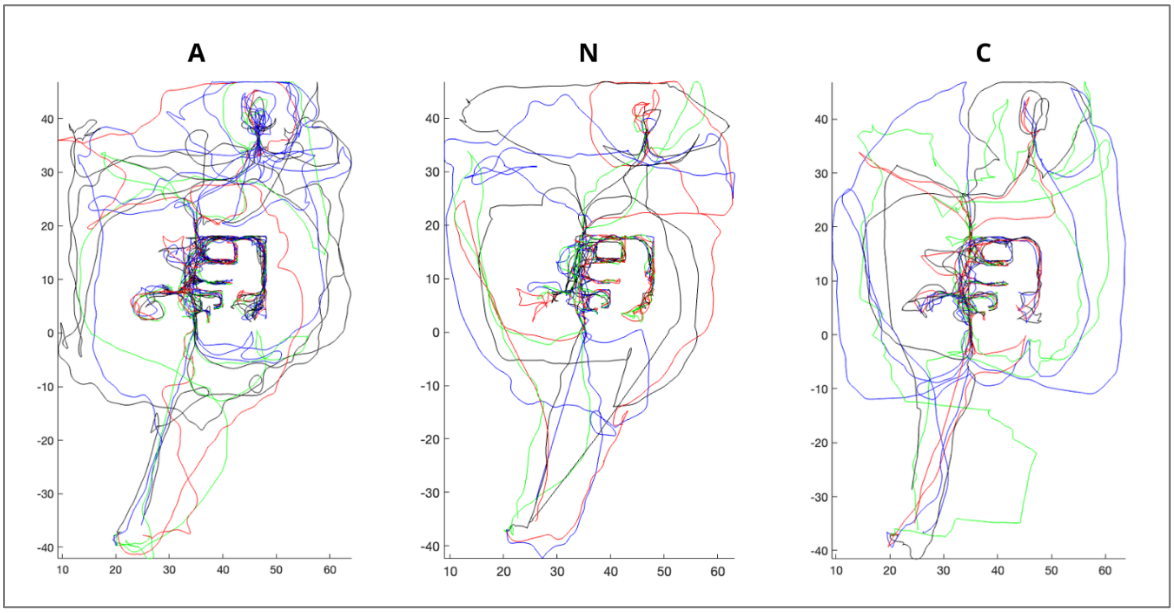

Figure 17: Interpolated movement data for the entire ground level for each scenario.

The full plot of the player movement in the yard or the first floor of the house also shows that the players in the anxious scenario were more interested in the shed in the backyard compared to the other scenarios, with some players spending an excessive amount of time there. The anxious scenario plot here is slightly more populated as well, showing that players in the anxious scenario covered more ground outside the house as well compared to other scenarios.

4.3.2 Hypothesis 5

As mentioned by Eysenck et al. (2007) experiencing anxiety could hinder executive function by increasing the importance of "outside stimuli". Based on this, it was also hypothesized that increasing anxiety levels in the music will cause disorientation and make it harder for players to spot the flaws in the game. Looking at how long it took for players to complete the given task should give a good indication of game difficulty and players' success in learning the new task, given the fact that all of them were playing for the first time. Different base skill levels should be accounted for, and while this information was not gathered from the participants, there were two clear outliers in terms of amount of camera movement, that could be indicative of less prior experience playing a first-person game on a gamepad controller. There was one outlier in the neutral scenario, and one outlier in the control scenario, so for those two scenarios it is a reasonable assumption they could skew the averages to the more difficult (slower completion speed) side.

Fourteen out of fifteen participants were able to find every flaw and finish the game in the 15 minutes they were given. The one participant who ran out of time finished the game with only five flaws found. As predicted, the two outliers based on camera angle movement (N2, C10) were also outliers in terms of total gameplay time within their respective groups, so it can reasonably be assumed that their longer gameplay time is most likely due to the controls being less intuitive, and not due to the change between scenarios. If these outliers are excluded, the average gameplay duration in the anxious scenario (*M* = 653.13s, *SD* = 173.49s) was nearly three minutes more than in the neutral (*M* = 454.81s, *SD* = 129.00s) or control (*M* = 474.58s, *SD* = 99.45s) scenarios respectively.

To examine the difference in game progression across the gameplay session, it is possible to look at the time spent finding each flaw individually. Some of the flaws are closer to each other than others and finding these clusters will show up as more consecutive shorter times between flaws. There are two rooms with more than one flaw in them, and these two clusters actually seem to be visible in the graph below as two dips in the line representing the time spent finding the flaws for each scenario (A, C, N). The graph also includes the previously mentioned outliers in the data, as the idea is to look at where the players take the most time relatively, and not how much absolute time each scenario spent for each flaw.

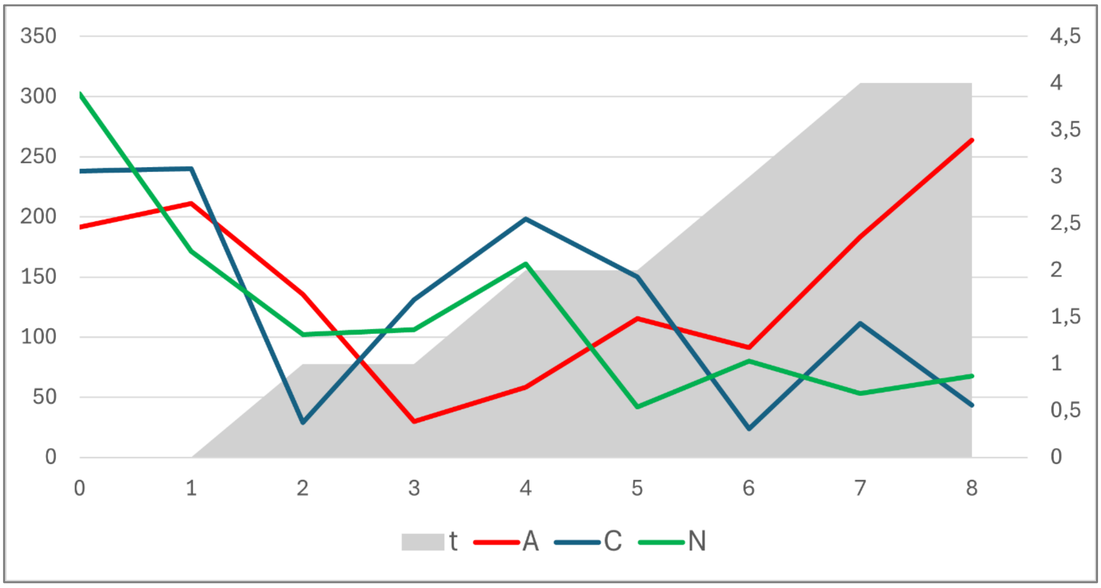

Figure 18: lines showing the average time spent finding each flaw for each scenario, with the onset of the musical triggers (t) visualized in grey.

The first flaw is in general the slowest to be found, and the next couple of flaws are found more easily. There was an observable rise in time spent around flaw 4 for the neutral and the control scenarios, and this is usually the part where the player must proceed upstairs to find more flaws. This was not the case for players in the anxious scenario. Once the player has reached upstairs, the remaining four flaws should be relatively fast to find, and for the neutral and control scenarios this did reveal itself as the last few flaws being on the faster side in both scenarios. This is backed up by statistical analysis, with Pearson correlation coefficiency analysis revealing a relatively strong inverse correlation between flaws found and time spent looking for flaws in the neutral (r = -.79, p = .012), and control (r = -.62, p = .076) scenarios. No such correlation exists for the anxious scenario, and it even shows a very weak positive correlation (r = .12, p = .76) with the number of flaws found. This is interesting for two reasons: finding the flaws should become easier as the game progresses and becomes more familiar, and 2) the time spent finding the flaws followed the onset of the musical triggers very closely after the first three flaws.

5 DISCUSSION

Music has a significant impact on a player's actions and the intensity of the emotional experience (e.g., Calleja, 2011; Jørgensen, 2017), and models to analyze player behavior have been developed in the study of games and human-computer interaction (e.g., Ravaja et al., 2006; Chertler et al., 2019; Wallner & Kriglstein, 2013). Methods of analysis specifically intended for reviewing video game music are still sparse (Medina-Gray, 2019), and this study provided a great opportunity to compare the efficiency of different data types. This study tested horror game music's effectiveness in inducing fear and anxiety by using physiological measures, and if this anxious response could be detected by looking at the player behavior data. Subjective interviews were also conducted to help correctly interpret the results.

The anxious scenario managed to induce a significant change in skin conductance levels compared to the neutral and control scenarios, but the effect was not present at similar strength for other measurements. A significant increase in horizontal camera movement was also observed in the player movement data for the anxious scenario but not the other scenarios. The players in the anxious scenario were on average the slowest to complete the game. In the neutral and control scenarios, the time it took for the players to find flaws was negatively correlated, indicating that the players learned the game and were able to detect and photograph flaws faster as the game progressed. This effect was not present for the anxious scenario, in which the last two flaws in fact took the longest to find. The anxious scenario also produced visually distinct movement patterns from the movement data.

5.1 Assessing the stimuli

Based on the results, the stimuli and the research setup performed as expected. The main concern mentioned in the methods section was that the game would not reach a sufficient level of immersion for the music to behave as expected. Luckily participants in all of the scenarios rated the game (and by extension the entire research experience) relatively high in terms of immersion. Some participants did mention the visual side of the game to be a bit lacking, which was to be expected, but even those who found the visual side to be lacking gave the game experience in general a decent evaluation in terms of immersion. The game difficulty was also very well balanced, where even experienced gamers had to focus on the task to complete it, and more novice gamers (bar one) were able to complete the task and learn the controls in the allotted time.

The other main concern was that the setting of the game would not be neutral enough to be interpreted differently enough depending on the music. Fortunately, this was not the case, and the neutral and control scenarios managed to make the players feel somewhat safe after noticing that there might not be anything scary after all, while the anxious scenario did rate higher in terms of scariness and the players mentioned consistently "looking out for some danger or enemy". The reason behind the initial scariness in the neutral and control scenarios can be somewhat attributed to the study being marketed as a horror game music study, so the players were expecting some horror elements. However, the music was able to change their expectations towards the game.

5.2 How well do anxious musical elements and sound design induce anxiety in a video game context?

The study was designed so that the only variable between scenarios was the music, so any changes between scenarios in the measurements could be attributed to the music. There are some disclaimers that can, and should, be made before proceeding, as there are a lot of factors that can affect the participants' experience of the stimulus. These can be things like previous experience with horror games or personality, for example. For the sake of this study, it was assumed that the participants shared a basic understanding of western music, and an understanding of digital games and media.

The SCL data analysis showed that there was a significant difference between group A in comparison to group N and group C, and groups N and C did not differ significantly from each other. SCL is an established measure of anxiety, as shown in the literature review (e.g., Kreibig, 2010; Nacke et al., 2010), and an increase in SCL as observed here, indicates an increase in arousal (e.g., Polat & Özen, 2023; Critchley, 2002) This result was congruent with the initial hypothesis set for this measurement. The SCR data analysis did not reveal any significant differences between groups, which differed from the hypothesis set for this measurement. SCR is a component of the fast-changing phasic activity of skin conductivity, which has also been linked to high arousal states and anxiety in previous studies (Kreibig, 2010). SCR is better used for observing event related reactions, and it is reasonable that analyzing the data as a whole would not yield any good results. There is data of the timestamps for major events in the game for each participant but combining them with the SCR data proved too much work for the timeline of this thesis project. This is, however, something we aim to do in the future. This was also proposed in their study by Grimshaw et al. (2010), as they only looked at tonic data and found it limited, suggesting that phasic data in relation to game events should be considered as an additional measurement (p. 341). However, the overall analysis of the GSR analysis showed highly promising results regarding the music's ability to actually induce measurable emotional responses during gameplay. The increase in the slow-changing tonic activity is a specifically strong indicator of anxiety, as anxious responses tend to last longer and change slower than fearful responses (Sylvers et al., 2011). The HRV analysis did not indicate any meaningful differences between groups either. Multiple variables generated via the HRVTool batch analysis function were further analyzed using ANOVA. It was noted that while the effect was not statistically significant, the mean HRV value for each participant in group A showed a decrease from baseline, whereas in groups N and group C both increased and decreased values were shown. A decrease in HRV is also an indicator of stress (Tiwari et al., 2021), and by extension, anxiety (Kreibig, 2010). These results could naturally be affected by the small sample sizes, due to which further research is required.

5.3 How does experiencing video game anxiety affect player behavior?

The anxious scenario managed to induce significantly more horizontal camera movement compared to the neutral and control scenarios. This was in line with the hypothesis of anxiety making the players look around more to detect possible threats and keep track of their surroundings. This could also be an indication of the player getting a bit more disoriented in the anxious scenario compared to neutral and control scenarios. The explanation of the players getting disoriented by the horror music scenario is also backed up by the players on average taking a longer time to complete the task in the anxious scenario. The effect was the strongest at the end of the anxious scenario, where the players took the most time finding the last two flaws. The last two to three flaws were the fastest to find in the two other scenarios pointing strongly in the direction of the effect being due to the difference between scenarios. The music also reaches its peak at the end of the session, so hypothetically the music's effect should be the strongest around that time as well. This result indicates an increase in the music's anxiousness made it harder for the players to complete the task. It makes for an interesting finding to further comment on Jørgensen's (2017) study where removing all audio caused the players to be ejected from the game (Jørgensen, 2017). Removing the music alone in the control scenario did not cause this, and it is probably because the ambient audio itself might have been enough to provide sufficient immersion to not be of harm. This finding of anxious music causing worse performance is also in line with the ideas presented in Grimshaw et alii (2013) who found highly complex music (such as ours) to be intentionally used to destabilize the players (Grimshaw et al., 2013). The effect of complexity in itself is an interesting thing to concern for future studies, as our horror music was on purpose more complex than the neutral music. In this study the music's complexity was positively correlated with the time it took for the player to find a flaw towards the end of the game in the anxious group. Future studies might examine this connection in more detail to see if the connection was based more on purely cognitive disorientation (interpretation of complex music taking away cognitive resources) or due to a change in the player's emotional state (an anxious emotional state making it harder to focus on the task at hand). This could be done by testing a similar gameplay situation with simple anxious music compared to complex anxious music.

Visually there was also a distinct difference in the movement patterns between scenarios. The anxious scenario produced more populated movement paths, where the same area was often covered multiple times by a single player. This could be an indication of the players being either more careful, or a little bit unsure of where to move. Restlessness is one experiential phenomenon often related to anxiety and stress, and the players pacing around more in the game could be a result of them being in an anxious or stressful state, as indicated by the physiological data as well. In one area of interest the players in the anxious group also employed a more careful approach compared to the neutral and control groups, when approaching a couple of flaws in the upstairs of the house. This effect is most likely due to the players interpreting the situation as being scarier based on the musical context.

While this kind of hermeneutic analysis of gameplay data can be a bit vague in producing quantifiable results by itself, it is very efficient in detecting features in the data that might be worth looking into further. In the case of this data, the movement patterns could be good material for machine learning or algorithmic classification. This kind of knowledge could lead to us being able to understand the players emotional responses to video games better through gameplay data only. This could be then applied to new or already existing games, to help the developers understand the emotional states of their players at scale.

5.4 How well do different types of data work in detecting and measuring anxious responses?

Both the physiological data and the gameplay data managed to separate the anxious scenario from the neutral and control scenarios. Noteworthy is that this study looked specifically for indicators of anxiety, and the takeaway is, that it was possible to distinguish the anxious scenario from the other scenarios with almost all of the chosen measures. Some measures of course did this more confidently than others.

The physiological measures on their own were not enough to distinguish between an anxious response although the SCL analysis was able to show a statistically significant effect between scenarios. However, when combining the physiological response with the anxious gameplay and interview data, many of the checkboxes for an anxious response can be checked.

The subjective interviews and ratings managed to highlight points where observations in the other types of data were attributable to some other factors than music. The numeric results and open questions directed towards the gameplay experience gave a good indication of how the stimulus performed overall, and how the game was perceived by the participants. The numerical scariness ratings given by the participants showed a similar pattern between scenarios as the SCL analysis and the mean y° axis movement. This means that at least these three measures seemed to work equally well in detecting the anxious scenario from the two non-anxious ones. This was expected for a comparison between EDA and subjective measures based on the work by Baldini et al. (2022), but this result shows promise in that gameplay data could make for an equally good comparison.

5.5 Limitations and restrictions

The study only had 12 participants in total, adding up to 4 for each scenario. This was enough to conduct the study and run an analysis, yet due to the small sample size the results should be taken with a grain of salt. People can respond to horror stimuli very differently based on previous exposure to the genre and personal preferences, for example. Horror in itself is a genre that splits the opinions of people to those who find it enjoyable and gravitate towards it, and those who avoid it as much as possible (Perron, 2018). This conclusion can be drawn from the tones of the answers to our questionnaire as well, with some players being delighted by the eventual lack of horror elements in the neutral and control scenarios, and others seemingly enjoying the suspenseful horror music environment in the anxious scenario. This discrepancy in the participants' personal preferences can definitely cause some bias with a small sample size.

The anxious scenario was also rated highest on fun, and it is possible that the reason behind the observed differences in the data was that the other two combinations of game and audio were not as engaging as the horror one. Horror elements could in themselves be more intense emotionally compared to pleasant elements. If this was the case, a follow up study could be to see if the difference in gameplay behavior and other responses could be replicated with some other style of emotionally intense music as well, and not just horror music.

Another possible criticism could be that the study setting itself lacked authenticity, as it took place in a controlled research environment which might feel unnatural to participants, who were also required to wear laboratory equipment (ECG and GSR sensors) under constant monitoring by the researchers. On the other hand, it was shown that even under these conditions the music had measurable effects on the participants, and thus it can be argued that the 'unnatural' setting managed to in fact strengthen the validity of the overall results.

5.6 Conclusion

The results of the study show that horror music indeed can induce an anxious response in the players without help from contextual horror elements. Based on the interviews and the gameplay data it can also be said that the anxious response made the players look for potential threats where they could not see them, further strengthening the interpretation of the emotional response as anxious by its lack of a clear target as highlighted by research (Sylvers et al., 2011; Eysenck et al., 2007). This is also in line with the theory of music alone not being able to define its target from Cespedes-Guevara and Eerola (2018) regarding the use of basic emotions in music research. This is related to the point of *the* horror music emotion of interest being anxiety instead of fear, although fear is more closely associated to horror games in general. It can be argued still that the game context was enough to where the concept of enemies was so familiar to the participants, that they would look for them even if they did not exist, thus making the players fear nonexistent enemies. This argument is well countered by the behavioral observations from the gameplay, where there were no fight or flight reactions or any other fear-typical reactions to the game environment with no visible dangers or enemies. The hypotheses based on anxious responses also held their own very well. Based on this, we can say that the term *anxiety* would best describe the emotion the players experienced, *induced* by the combination of horror music and the game.

The question of whether or not the experience was *real anxiety* or *artistic anxiety* is still up for debate as although the behavioral and physiological hypotheses from psychology matched the results well, the players had fun playing the game. This could mean that real and artistic anxiety would rely on the same human response despite the difference in the interpretation of the experience as serious or, in this experiment's case, playful.

The way the addition of music on its own was able to consistently modify player behavior could prove interesting for therapy games, where this could be used to promote certain strategies or approaches. The games could also feature algorithms that would interpret gameplay patterns related to specific emotions. The ability to detect these patterns could help create games that adapt to emotional states of players much like MindLight (Wols et al., 2018; Schoneveld et al., 2016), but without the need for external devices like eye-trackers or biofeedback sensors. Commercial games could also benefit from developing systems for player emotion detection by having their games interact more closely with the player's emotional state, making them more responsive and engaging. The results are encouraging for future research.

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APPENDICES

APPENDIX 1: NOTIFICATION

JYVÄSKYLÄN YLIOPISTO
UNIVERSITY OF JYVÄSKYLÄ

THE EMOTIONAL EFFECTS OF MUSIC IN VIDEO GAMES

Mandatory questions are marked with a star (*)

Player survey and request to participate in the survey

You are asked to participate in a video game study, which examines the player's behaviour and physical reactions in relation to video game content. The aim of the study is to outline possible correlations in the players' measurable physical and cognitive responses during gameplay, in order to better understand the relationship between emotions and gameplay performance. If the description of the study interests you, we hope you will consider registering as a participant!

Participating in the study requires that you are over 18 years old, non-smoking and in basic health. The examination includes both visual and auditory elements, so you must have normal vision (glasses and contact lenses are allowed) and normal hearing. Participation requires that you do not have a hearing aid. During the test, you will be asked to play a video game that requires your hands and fingers to function normally. Using a wheelchair is not a restriction for participating in the study. Before the session, we will go over the exclusion criteria with you to confirm your participation.

Participating in the study also requires that you meet the following criteria:

- You have NOT been diagnosed with a disease or symptom that significantly affects the functioning of the heart or circulatory system, which requires medication and/or other regular treatment.
- You have NOT been diagnosed with a neurological disease or symptom that significantly limits your ability to function, which requires medication and/or other regular treatment.
- You have NOT been diagnosed with a disease or symptom that significantly affects the function of the peripheral nervous system, which requires medication and/or other regular treatment.
- You have NOT been diagnosed with a severe sleep disorder that requires medication and/or other regular treatment.
- You have NOT been diagnosed with a neuropsychiatric disease, a disease that significantly limits your ability to function, or a symptom that requires medication and/or other regular treatment.
- You have NOT been diagnosed with a mental health disorder that requires medication and/or other forms of treatment.
- You have NOT been diagnosed with an anxiety disorder.
- You have NOT been diagnosed with an addiction disease, and you do not abuse alcohol, drugs or narcotics.
- You have NOT been diagnosed with any other disease or symptom that causes severe symptoms and significantly limits your ability to function, and requires medication and/or other regular treatment.

If, based on existing symptoms, you suspect that you have a mental health disorder that requires medication and/or other treatment, but which a doctor has not yet diagnosed, **DO NOT** register as a participant in the study.

This announcement describes what happens during the study. The attachment describes the processing of your personal data. Approximately 30–40 adults will participate in the study. This is a one-off study and you will not be contacted again later.

Voluntariness

Participation in this study is voluntary. You can refuse to participate in the study, stop participating or cancel your previously given consent, without stating any reason for this and at any time during the study. This will have no negative consequences to you.
If you cancel your consent for the processing of your personal data, the personal data, samples and other information collected about you up to that point cannot be dealt with as part of the study but must be deleted as far as their erasure from the data is possible.

Progress of the study

During the study you are asked to play a specifically designed video game that tests your observation and emotion regulation skills. The study will take place in Musica (M-building) at the University of Jyväskylä (Seminaarinkatu 15). The study will be conducted in May of 2024. The exact date and time will be arranged via email.

The examination takes about 45-60 minutes, and is one-time. The experiment has three different groups. Each group is assigned a different version of the game, varying in the level of the game's emotional content. You will get to know which group you belonged to after the interview portion.

In the research situation, you will be asked to play a video game. For the study, sensors which collect physical data about you (heart rate, heart rate variability, and galvanic skin response) are attached to your fingers and wrists. Attaching and using the measuring sensors will not cause you any discomfort or pain. Before starting the gameplay, you will have a moment to relax and get comfortable with the game controls.

The gameplay part of the study lasts for about 15 minutes. You will be playing a game in which, as part of your job at a property maintenance company, you will inspect a rental house for flaws after the tenants have moved out. If you spot a flaw, your task is to photograph it. You can open doors, walk around, and use the camera functionality. The game is played in first person, and you will use a standard game controller to control the character. The game contains suspense/horror elements.

After playing, the measurement sensors are removed and you are briefly interviewed. An audio recording of the interview will be recorded, which will be transcribed into text. After transcription, the audio recordings are destroyed. The interview/debrief session lasts up to 15 minutes. During the study, two people responsible for the research are present with you. They will observe and take notes, monitor the research equipment and take care of the safety of the research situation. They will guide you if necessary and you can ask them to stop the test at any point.

You will not be contacted after the examination day. If you wish, you can inquire about the progress and results of the research from the persons responsible for the research.

Possible benefits from the study

With the help of research, it is possible to produce quite concrete data about the effects of certain special features of video games on the player, which can prove to be very useful, for example, in research aimed at developing means of improving emotional regulation skills or well-being using video game based interventions. The research can also benefit game developers in better understanding and measuring the effects of game design choices and content.
The study views a phenomenon from a new perspective, and it can therefore contribute to increasing knowledge on an important theme.
The data collected in the research situation does not provide the subject with useful information about their own body, for example, and the subjects are not given a personal report.

Possible risks, harm, and inconvenience caused by the study as well as preparing for these

During the gameplay, elements of suspense and horror are displayed, which may cause you to feel temporarily uncomfortable or anxious. The game's age limit recommendation corresponds to the PEGI 12 rating, according to which the game's material is therefore suitable for people over 12 years old. However, if you feel that horror games or, for example, horror movies evoke significantly strong negative emotions in you, and/or last for a disproportionately long time after the game or movie ends, or even cause recurring nightmares, you should carefully consider whether you want to participate in the study. However, the game is short and does not contain particularly shocking material such as violence or sexual content. If you are experiencing uncomfortable levels of anxiety, panic attack, or you simply don't feel like continuing, the session can be immediately stopped. You will have time to relax and reorientate in a private space, and if necessary, you will be assisted by the researchers.

The research situation does not involve the possibility of other harms.

Study-related costs and compensations to the subject as well as research funding

No rewards will be paid for participation in the study. The research has no funding and is not (nor are the researchers) financially connected to any third party operator, such as video game industry.

Informing about research results and research outcomes

The subjects are not informed about the results separately. The research will be published as part of a Master's thesis, and after publication it will be publicly downloadable from the JYX publication base of the University of Jyväskylä. Information related to the study can be inquired from the study implementers. The collected data is anonymized before publishing. Research subjects cannot be identified from the results or publications related to the results.

Insurance

The University activity and the subjects are insured. The insurance contains malpractice insurance, liability insurance and accident insurance. The subjects are insured for external risks, accidents, and injury for the duration of the research session. The liability insurance is valid during the measurements and the commuting directly related to the study.

Contact persons for further information

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A LINK TO THE PRIVACY NOTICE:

https://drive.google.com/file/d/1zif3ioacr7CiCiogL2xxBrpJ7F2FmDCl/view?usp=sharing

1. I have read and understood the information written above, and I agree with its terms. *

◯ Yes

2. I have read and understood the privacy notice (see attachment), and I agree with its terms. *

◯ Yes

3. I wish to participate in this study, and I may be contacted via email to schedule a session. *

◯ Yes

4. Email address for contacting: *

Email: *

Email again: *

APPENDIX 2: ANXIOUS MUSIC SPECIFICATIONS

ANXIOUS MUSIC TABLE								
LAYER ONE								
TRACK	**INSTRUMENT**	**SOUND**	**INTERFACE**	**PAN**	**PLUGINS**	**BUSES**	**AUTOMATION**	**DESCRIPTION**
1	Speculative Memories by Yair Elaza	"Textures: piano tape swarm"	Spitfire Player	LEFT -14				*Long repeating notes. Swarms of piano keys, ambient, airy, little motion, tape sounds*
2	Tape Orchestra by Spitfire LABS	"Strings Flautando"	Spitfire Player		1. Direction Mixer (Logic) 2. Space designer (Logic)			*Mix between synth and strings, airy, ambient* *High / Low split, reverse delay*
LAYER TWO								
TRACK	**INSTRUMENT**	**SOUND**	**INTERFACE**	**PAN**	**PLUGINS**	**BUSES**	**AUTOMATION**	**DESCRIPTION**
1	Ethereal Earth by Native Instruments Play Series	"Control group"	Komplete Kontrol	RIGHT +3	1. Direction Mixer (Logic) 2. Space designer (Logic) 3. Step FX (Logic)	1. Replika XT (Native Instruments) 2. Trash (iZotope) 3. Freak (Native Instruments)	Step FX wet/dry mix programmed with Minilab 3	*High / Low split, reverse delay*
LAYER THREE								
TRACK	**INSTRUMENT**	**SOUND**	**INTERFACE**	**PAN**	**PLUGINS**	**BUSES**	**AUTOMATION**	**DESCRIPTION**
1	Glass Piano by Spitfire LABS	"North Star"	Spitfire Player	Right +4				*Slightly choppy, clear, airy, high range*
2	Alchemy Soundscapes by Logic	"Scary Zone, zone 1"	Alchemy	see automation			ear-to-ear panning programmed with Minilab 3	
LAYER FOUR		Glitchy, moving, human, bugs, desperate, doom, melancholic						
TRACK	**INSTRUMENT**	**SOUND**	**INTERFACE**	**PAN**	**PLUGINS**	**BUSES**	**AUTOMATION**	**DESCRIPTION**
1	Lap Steel by Spitfire LABS	"Resonance chaos"	Spitfire Player	see automation	1. VocalSynth (iZotope) 2. Space Designer (Logic) 3. Phasis (Native Instruments)	1. Replika XT (Native Instruments)	ear-to-ear panning programmed with Minilab 3	*Glitchy, moving, human, bugs, desperate, doom, melancholic*
2	Dulcimer by Spitfire LABS	"Tremolo"	Spitfire Player	see automation	1. Space Designer (Logic)	1. Replika XT (Native Instruments)	ear-to-ear panning and expression automation programmed with Minilab	*Melancholic, desperate, follows track one*
3	Alchemy Sound Effects by Logic	"Dark Arrangement FX, dark woosh"	Alchemy	RIGHT +23			Expression and volume automation programmed with Minilab 3	*Quick sweep, noise burst, buzz*
TRIGGER "SAW"								
TRACK	**INSTRUMENT**	**SOUND**	**INTERFACE**	**PAN**	**PLUGINS**	**BUSES**	**AUTOMATION**	**DESCRIPTION**
1	Speculative Memories by Yair Elaza	"Double bass: distorted swell"	Spitfire Player				Pitch bend, expression and volume automation programmed with Minilab 3	*heavy, distorted, pulse, pressure, low*
2	Analog Lab by Arturia	"Myllness"	Analog Lab				Expression and volume automation programmed with Minilab 3	*low, rumble, pressure, heavy*
TRIGGER "SIREN"								
TRACK	**INSTRUMENT**	**SOUND**	**INTERFACE**	**PAN**	**PLUGINS**	**BUSES**	**AUTOMATION**	**DESCRIPTION**
1	Alchemy Soundscapes by Logic	"Calling Darkly: Drone wash"	Alchemy	see automation			Ear-to-ear panning, pitch bend and volume automation programmed with Minilab 3	*siren, doom, panic, modulation*
2	Alchemy Soundscapes by Logic	"Fluttering drones: Dark drone"	Alchemy				Pitch bend automation programmed with Minilab 3	*ears ringing, TV emergency beep*
TRIGGER "PRESSURE PULSE"								
TRACK	**INSTRUMENT**	**SOUND**	**INTERFACE**	**PAN**	**PLUGINS**	**BUSES**	**AUTOMATION**	**DESCRIPTION**
1	Alchemy Sound Effects by Logic	"Looming in Shadows: Lurking"	Alchemy				Expression and volume automation programmed with Minilab 3	*pulse, glitch, machine, pressure*
2	Alchemy Soundscapes by	"Colossal Machine: Machine"	Alchemy					*heavy, low, slow pulse, growl, machine*
3	Analog Lab by Arturia	"Depth Impact"	Analog Lab		Neutron 4 (iZotope)			*sub bass hit*
4	Alchemy Sound Effects by Logic	"Artificial Hearbeat"	Alchemy					*heartbeat*
TRIGGER "ANXIOUS DRONE"								
TRACK	**INSTRUMENT**	**SOUND**	**INTERFACE**	**PAN**	**PLUGINS**	**BUSES**	**AUTOMATION**	**DESCRIPTION**
1	Alchemy Soundscapes by Logic	"Dark Doesn't Matter: Breath"	Alchemy	see automation		Replika XT (Native Instruments)	ear-to-ear panning and expression automation programmed with Minilab 3	*speech-resembling, demon, whisper*
2	Alchemy Soundscapes by Logic	"Far Away Droning: Low Drone"	Alchemy				pitch bend automation programmed with Minilab 3	*low, heavy, ambient*

APPENDIX 3: NEUTRAL MUSIC SPECIFICATIONS

NEUTRAL MUSIC TABLE								
LAYER ONE								
TRACK	INSTRUMENT	SOUND	INTERFACE	PAN	PLUGINS	BUSES	AUTOMATION	DESCRIPTION
1	Alchemy Soundscapes by Logic	"Soft Fluctuations, Drone 1"	Alchemy	see automation			ear-to-ear panning programmed with Minilab 3	*Airy drone, slow, mid-range, major chords*
LAYER TWO								
TRACK	INSTRUMENT	SOUND	INTERFACE	PAN	PLUGINS	BUSES	AUTOMATION	DESCRIPTION
1	Alchemy Soundscapes by Logic	"Ambient Drift, slow filter"	Alchemy	Left -10				*Filtered sweeps accompanying layer 1 harmonically; slow, distant*
LAYER THREE								
TRACK	INSTRUMENT	SOUND	INTERFACE	PAN	PLUGINS	BUSES	AUTOMATION	DESCRIPTION
1	Glass Piano by Spitfire LABS	"North Star"	Spitfire Player	Right +4				*Slightly choppy, clear, airy, high range*
TRIGGER "PARTICLES"								
TRACK	INSTRUMENT	SOUND	INTERFACE	PAN	PLUGINS	BUSES	AUTOMATION	DESCRIPTION
1	Analog Lab by Arturia	"Autumn Fireflies 1"	Analog Lab	Right +14				*Clean, bell-sounding, short, high*
TRIGGER "PIANO"								
TRACK	INSTRUMENT	SOUND	INTERFACE	PAN	PLUGINS	BUSES	AUTOMATION	DESCRIPTION
1	Hybrid Keys by Native Instruments	"Athmospheric"	Komplete Kontrol			Space Designer		*Muted piano, textured, calm, major chords*
TRIGGER "SYNTH PULSE"								
TRACK	INSTRUMENT	SOUND	INTERFACE	PAN	PLUGINS	BUSES	AUTOMATION	DESCRIPTION
1	Analog Lab by Arturia	"Old Strings"	Analog Lab	Left -9	Step FX: Syncopated Pulse		Volume automation	*Pulsating, high, synth-string*
TRIGGER "GUITAR"								
TRACK	INSTRUMENT	SOUND	INTERFACE	PAN	PLUGINS	BUSES	AUTOMATION	DESCRIPTION
1	Session Guitarist by Native Instruments	"Electric Sunburst: 3-4 Arpeggio"	Komplete Kontrol	see automation	Space Designer: Guitat Hall	1. Phasis: classic stereo 2. Replika XT: width warm	ear-to-ear panning programmed with Minilab 3	