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The impact of music in gameplay using physiologic measurements

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Resumo

A indústria de jogos, em constante evolução, tem crescido significativamente à medida que os videojogos se tornam mais cinematográficos, imersivos e acessíveis. As trilhas sonoras aprimoram a imersão imaginativa dos jogadores, aprofundando a experiência de jogo e conferindo à atmosfera uma sensação mais genuína. Nesse sentido, esta tese examina como diferentes características musicais podem afetar o desempenho e as experiências dos jogadores, ao mesmo tempo que investiga as respostas fisiológicas associadas. Embora seja inegável que a música desempenha um papel significativo nos videojogos, mais pesquisas são necessárias para determinar como ela afeta o jogo e a experiência dos jogadores. Ao examinar a relação teórica e empírica entre músicas e as respostas fisiológicas dos jogadores, este trabalho busca preencher essa lacuna. Investigamos os efeitos potenciais da música através de respostas fisiológicas, no desempenho de jogo e na experiência por meio de testes com protótipos de jogo e composições com duas características diferentes, tempo e tonalidade. A metodologia usada envolveu o desenvolvimento de seis composições musicais com variações específicas de tempo e tonalidade. Os participantes jogaram diferentes versões, acompanhadas pelas diferentes músicas, enquanto suas respostas fisiológicas e feedback emocional eram registrados. As medidas fisiológicas usadas foram EMG, ECG e EDA. Ao analisar os dados, buscamos entender como a música e o desempenho dos jogadores interagem, o que ajudará os desenvolvedores de jogos a criar experiências mais imersivas e agradáveis. Este estudo abre possibilidades para aprimorar o uso de música como um componente crucial da mecânica de jogo e aprofundar a compreensão de como a música afeta os videojogos. Em conclusão, esta tese oferece um avanço à compreensão de como as características musicais influenciam as experiências de jogo dos jogadores. Os resultados deste estudo podem ser aplicados para desenvolver experiências de jogo inovadoras e emocionalmente estimulantes, enquanto mergulhamos mais profundamente no mundo dos videojogos.

Abstract

The ever-evolving game industry has grown significantly as video games become more cinematic, immersive, and accessible. Soundtracks improve players' imaginative immersion, which deepens the gaming experience and gives the atmosphere a more genuine feel. Therefore, this thesis examines how different music characteristics can affect players' performance and experience while examining physiologic responses. While it is undeniable that music plays a significant role in video games, more research is required to determine how it affects gameplay and player experience. By examining the theoretical and empirical relationship between soundtracks and players' physiologic responses, this work seeks to close this gap. We investigate the potential effects of music on physiological measurements, gameplay performance, and experience through user testing with a game prototype and compositions featuring two different parameters, tempo and tonality. The methodology used involved developing six music compositions with specific tempo and tonality variations. Participants engaged in gameplay sessions, accompanied by their respective soundtracks, while their physiological responses and emotional feedback were recorded. The physiologic measurements used were EMG, ECG, and EDA. By analyzing the data, we aimed to learn how music and player performance interact, which will help game developers develop more immersive and pleasurable gaming experiences. This study opens up possibilities for improving the use of soundtracks as a crucial component of gameplay mechanics and improving our understanding of how music affects video games. In conclusion, this thesis offers a step toward understanding how music characteristics influence players' gameplay experiences. The results of this study can be applied to develop innovative, emotionally stimulating gaming experiences as we delve deeper into the world of video games.

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"Research is formalized curiosity. It is poking and prying with a purpose."

Zora Neale Hurston

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Abbreviations

IFMCA	The International Film Music Critics Association
HMMA	The Hollywood Music in Media Award
CAM	Congruence-Associationist Model
PTSD	Post-Traumatic Stress Disorder
DAW	Digital Audio Workstation
GSR	Galvanic Skin Response
EDA	Electrodermal activity
ECG	Electrocardiogram
EMG	Electromyography

Chapter 1

Introduction

Since the rise of video games in 1970, they managed to position themselves with considerable popularity, although they were limited due to existing technology. However, the industry has been growing consistently in the past decades thanks to aspects such as the development of personal computers and consoles in the 1980s. Technology advancements are not the only aspect that has contributed to the popularity of video games but also the rise of online and mobile gaming, which allow players to connect with others wherever they are, increasing the social view of games and making them more appealing. There have also been heavy investments in marketing and advertising to help raise awareness of new games and attract new players. Furthermore, due to the rise of digital distribution platforms, the high availability of games is an essential factor in collaborating to evolve and adapt the industry, which is expected to help with video games' popularity.

Video games have been influenced by cinema since the early days of the industry and leveraged by the improvements in technologies and techniques; games are becoming more advanced. They have started incorporating more cinematic elements such as pre-recorded cutscenes, full-motion videos, voice acting, improved graphics, and interactive storytelling, a trend expected to keep evolving and establishing importance in future games. Another aspect of the cinematographic sector that has been profoundly influencing video games is music and sound effects. Nowadays, many games feature orchestral scores and sound effects designed to produce tension and drama and create immersion, a fundamental element to developing a relationship between the player and the game. Collins (2013) considers that the principal function of sound in games is enhancing the player's interactivity with the game, aiming to create the most immersive experience possible. For that reason, music and sound design are becoming critical elements in game design and development.

1.1 Problem

As mentioned before, video games have taken the film industry as inspiration for many aspects, music being one of them. They advanced alongside the game's narrative and capabilities in a few decades, becoming increasingly interactive, expressive, and complex.

For Donnelly et al. (2014), the lines between games and other media are growing thinner. However, as noted by Donnelly et al. (2014), many scholars have overlooked music's essential role in the gameplay experience, often focusing exclusively on the aural elements. There are still many definitions of video games that only consider the visual feedback generated by an interface to interact with the player, ignoring the importance and impact of music.

Furthermore, according to Bogost (2011), there is a fundamental property between music and games: "both are playable, offering their listeners and operators an expressive experience within the framework of melody and rhythm." That is, this expressive experience comes from the player's interpretation, which makes it a subjective field of study, as people with different backgrounds and personalities might have different interpretations of how music can affect gameplay. Thus, as also noticed by Wöhrman and Ningalei (2018) in their paper that aimed to study the impact of sound on player experience in a scenario of horror games, it is hard to measure the influence of sound in games. Even if it plays a considerable part in the games, the effects of sound and its measurements can differ from person to person. This difficulty in establishing a consistent measurement might be one reason why few researchers are still exploring the field. This subjectiveness of how the player feels about the game world is also considered by Collins (2013) as a deeply personal and a multifaceted process where certain factors, such as vocality, may strengthen one player's degree of immersion while simultaneously destroying another's.

Nevertheless, a few studies still exist on music's impact on players' emotions, behaviors, and engagement during games. For example, music with a faster tempo can generate excitement and adrenaline, while slower music can cause calm and relaxation. In addition, studies show how soundtracks can be crucial to create immersion and increase player engagement, which is an essential factor in game design to promote a better experience for the player and are studied by many authors like Collins (2008), and Grimshaw-Aagaard (2011).

However, there is still a need for a more profound knowledge of how different music parameters and aspects can affect and impact a player's performance using more techniques and methods, for example, to better understand the mechanisms that underlie the effects of music on players. In this sense, using physiological measurements could represent a suitable method. Finally, given the recent increase in knowledge of the importance of music in video games, deeper studies and research in this field are necessary to improve the game itself and the experience it gives to a player.

1.2 Motivation

Music can play many essential roles in a video game and affect and impact the player's performance in various ways, not only during gameplay but also how it can affect the player's perceivement of the game afterward.

For example, in Tuuri et al. (2021) research, where they aimed to identify the impact of music within and beyond gameplay, their results showed that for almost 40% of the respondents, game music had influenced their game choice considerably. In the same survey, more than 50% of

the respondents said that game music had been a reason for them to replay the game. In this sense, their data indicated that music could go beyond the gameplay moments and cause further influence, both in the initial decision to choose a new game and on retention, that is, to keep playing and returning to the game.

Also, according to Diaz-Gasca (2015) study, the memories evoked by game music are usually valuable experiences for players. Those memories are often related to the game world, its events, feelings, and aesthetics. This shows the impact of music on emotion evocation, in which music can evoke emotions in the listener. For video games, it can enhance the story's emotional impact, making it more engaging and memorable.

Considering one of the aspects in which music shows great importance is *immersion*, which is mentioned by many authors such as Collins (2013) and Grimshaw-Aagaard (2011), where music plays a crucial role in immersing the player in the world, assembling a sense of atmosphere and emotion, and can help to develop an understanding of tension, drama, or mystery, connecting the player to the game and the story.

Another vital aspect that music can assist is *storytelling*, as it can be used to advance the game's story and to share information about the game world and the characters. Music might also create memorable moments and help players recall specific locations, characters, or events from the game.

Furthermore, it is worth noting that many games incorporating music as part of the gameplay are often referred to as *rhythm games*. The player must perform actions in time with the music to progress through the game, such as "Guitar Hero," "Just Dance," and "Beat Saber." These games are a great example of using music as a central gameplay component.

Additionally, using popular music in rhythm games has helped making them more appealing to a broader audience. Lastly, music can also be an essential part of a game's *branding* and create a sense of identity, managing to differentiate a game from others in the same genre.

Furthermore, *User experience* is a study field that is expanding and becoming increasingly influential in the game industry as it can substantially impact a game's success. Several factors, including the increased importance of player engagement and immersion and the importance of player retention, have driven this growth. A good user experience can also help to make a game more accessible to a broader range of players, including those with disabilities or those who are new to the game. From the companies' or distributors' point of view, a good user experience can also help create a positive brand image for a game and differentiate it from other games in the same genre. Finally, it can also increase revenue by making it more engaging, leading to more purchases, subscriptions, and overall player loyalty.

Given all of these factors that music can affect in games, it clearly shows the importance of conducting further studies on music's impact. Furthermore, some research is also being done to better understand the player experience and further improve game design, as developers can create a more compelling game design after comprehending how music affects players, enhancing the player's experience, and improving the game's retention, increasing the overall engagement. Thus, as the field of game studies is relatively new, those studies can help advance the understanding of

how games can be used to create new experiences, which can also help improve the overall game industry and lead to more successful games.

1.3 Goals

Given the context mentioned, this work will research and try to discover the answers to questions the questions:

RQ1: Can one measure the impact of specific music characteristics variations on a player's game experience and performance, and if so, how?

RQ2: Can physiological measurements be used as part of that assessment, and how?

This should be done by producing a composition, developing a game level, and promoting tests to analyze the impact of each type of music on the player's performance and physiological responses.

For that purpose, a few aspects need to be regarded. For example, how different types of compositions, that is, using contrasting and disparate characteristics in music compositions, such as tempo and tonality, might impact the player's overall performance and perception of the game.

Furthermore, a few physiological responses of the player will be measured to help support the analysis and see if there is a relationship between each music parameter and the physiological responses.

1.4 Document Structure

This document consists of the following sections:

Chapter 2 regards a literature review regarding state of the art, covering aspects such as the background and the influence and use of music in other fields.

In Chapter 3, the proposed solution is detailed, as well as the methodology expected to be applied to support and develop the research. This chapter will also explain and detail the game development and mechanics, the composition of the music, and its integration into the game.

Chapter 4 will cover the results and analysis of the questionnaire used in the tests and the recordings of the physiologic responses, as well as the experimental setup, protocol, and equipment used, and explain aspects such as participant selection and recruitment.

Next, chapter 5 is a discussion of the results obtained, as well as the limitations of the study.

Lastly, chapter 6 is the conclusion of the dissertation, recapping what was done, how and the final remarks. Additionally, some future work will also be suggested.

Chapter 2

State of the art

This chapter will cover aspects of the literature review involved during the research, including topics such as the background and related fields.

The background, present in section 2.1, demonstrates the position and situation of the current video game industry. The role and impact of music and sound effects in video games are present in section 2.2. Section 2.3 defines and explains the relation between music, video games, and physiological responses and measurements. Furthermore, a few related fields of application are mentioned and analyzed in section 2.4, for instance, the use of music in cinema and medicine and how it could be related and used to help further studies of the impact and use of music in video games. Lastly, the chapter closing remarks are presented in section 2.5.

2.1 Background

The video game industry is currently one of the most profitable and fast-growing segments in the entertainment industry. According to Clement (2023), it is estimated that the global gaming market will amount to 268.8 billion dollars in 2025, up from 178 billion dollars in 2021. Notably, these numbers are frequently changing as the industry could be deeply affected by the global economy and external factors. Additionally, a study from 2021 shows that the number of gamers was estimated at 2.96 billion. It is estimated that this number will surpass 3 billion in 2023. Branka (2023)

The game industry not only englobes video game development but also encompasses a wide range of activities and components, such as game publishing, which includes marketing, distribution, and the sale of games. There is also the **production of hardware**, like gaming consoles, personal computers, and other devices. Another element currently increasing and showing relevance is the **streaming and online services** that include streaming gameplay footage on multiple platforms. Furthermore, **merchandising** and **licensing** are also fields of great importance for the industry, as their revenue in the video game industry can be significant. It can include income from selling related merchandise such as clothing and collectibles and revenue from licensing games for use in other media.

As mentioned, the gaming industry has experienced significant growth in recent years. Today, 66% of Americans, more than 215 million people, play video games regularly (Entertainment Software Association (2022)). Technological advances have been a critical factor in favoring this growth, as they have allowed for more realistic and immersive games. Also, given the further development of online and mobile gaming, it was possible to reach a wider audience, as according to Entertainment Software Association (2022), 70% of users would rather play with smartphones than other consoles. Thus, the popularity of games is attracting more consumers, which increases the demand for games and services. This demand has been fundamental to attracting more investment and innovation and developing greater diversity in the overall industry to cater to different preferences and appeals of players.

2.1.1 Music Awards for Videogames

Game awards were established in the late 1970s and early 1980s when the industry started. These early awards, frequently presented by gaming publications and magazines, were created to honor the previous year's best games and game developers. Nowadays, they measure what the industry considers excellent games and aid in directing game innovation and development. Additionally, they offer players the chance to discover new games and developers.

As the gaming industry has grown and matured, it has significantly impacted the creation and evolution of game awards, increasing the number of awards and establishing greater recognition. It also affected the increase in competition, which has led to a higher quality standard in games.

With the formalization of game awards, containing an extensive range of categories, many awards shows were created, such as The Game Awards[1], The BAFTA Games Awards[2], The DICE Awards[3], and The GDC Awards[4].

A feature that is common in game awards is music-related categories, such as "best original score," "best song in a game," and "best soundtrack."

Aside from game awards, there are also other shows for awarding soundtracks in games that are not only game-focused but from the entertainment and music industry in general, such as The International Film Music Critics Association (IFMCA) Awards[5] and The Hollywood Music in Media Awards (HMMA)[6].

Those awards recognize the creative excellence of the music, showing the ability to create an impact and highlight the role of music as a tool for storytelling and evoking emotions in the player. Thus, they encourage developers and designers to discover new ways to enhance the gaming experience.

[1] https://thegameawards.com/
[2] https://www.bafta.org/games
[3] https://www.interactive.org/
[4] https://gamechoiceawards.com/
[5] http://filmmusiccritics.org/
[6] https://www.hmmawards.com/

2.2 Music and Sound Effects in Videogames

Many authors describe several ways music can affect player performance. Collins (2013) demonstrates that one of the main functions of sound in games is to enhance player interactivity to create the most immersive experience. Grimshaw-Aagaard (2007) agrees and complements this idea, as he considers player immersion a scenario where virtuality turns to reality, further developing the importance and impact of immersion.

Jörgensen (2017) considers two strands of audio in games: alert and communicate information to the player and the emotional involvement of the gamer. Also, according to Klimmt et al. (2019), soundtrack music should influence the players' sense of spatial presence and identification with the protagonist. Spatial presence refers to being physically in a virtual environment, as in a game.

Finally, for Summers (2011), music in games is designed to make the media more captivating. It also helps characterize the narrative and the characters, which are used to link the cutscenes and the main story.

As mentioned, different types of soundtracks can significantly impact performance and player perception in video games:

- **Upbeat and fast-paced music**: This type of music can increase excitement and adrenaline, leading to improved reaction time and increased motivation to play. It is often used in action and racing games like Mario Kart or even sports and arcade games like FIFA or Donkey Kong, creating a sense of excitement and challenge.
- **Relaxing and slow-paced music**: Might promote calm and relaxation, improving focus and concentration. It is commonly used in puzzles, games of strategy, or simulation games such as The Sims to create an atmosphere of realism and tranquility.
- **Ambient music**: Can create a sense of atmosphere and immersion, leading to improved engagement and enjoyment of the game. This type of music is often used in open-world or adventure games to develop a sense of exploration and discovery, such as in The Legend of Zelda.
- **Music matching the game's theme or era**: It can further develop a sense of atmosphere and immersion, which can lead to improved engagement and enjoyment. It is frequently used in games with a specific setting or genre, like fantasy or horror.

Sound effects and music are often considered separate audio elements in video games and other media. However, they are closely related and can work together to create an immersive experience. They are typically defined as audio elements used to create a sense of realism and enhance the game's atmosphere.

For Marks and Novak (2008), sound effects exist specifically to provide feedback to the player, immerse them inside the virtual world, and deliver an entertaining experience. They also define the many purposes of sound effects, such as setting the mood, adding realism, providing clues to

surroundings, enhancing entertainment value, creating tactile and interface feedback, and establishing a brand identity.

Furthermore, Nacke et al. (2010) noticed that the impact of music on a player's experience might be different when sound effects are present or absent. Grimshaw-Aagaard (2011) reinforces the idea that sounds effects and ambient sounds are significant for immersing and involving the player emotionally, as many of the sound stimuli that reach our ears are processed subconsciously, naturally handling these sounds. He then hypothesized that this supports the idea that sound fits well to add to the complete immersion experience in the game.

Lastly, Grimshaw-Aagaard (2011) implicated that as the border between music and sound effects is becoming blurred, the emotional qualities of music might also be applied to other types of sounds.

Overall, both sound effects and music are essential components of the audio design of a video game and can be used concurrently to create an immersive experience for the player. In conclusion, a well-composed soundtrack can make a game more memorable and enjoyable as well as contribute to a game's commercial success.

2.3 Music, Video Games, and Physiological Responses

Research on the physiological effects of music is an active field, and new findings are constantly emerging. However, there is still a long way to go, as music therapy is still considered a controversial field.

Music can cause a wide range of physiological responses in people, depending on the individual and the type of music. Music can generate several physiological responses, such as **heart rate**, **blood pressure**, **respiration rate**, the **release of certain hormones**, and **evoking muscle activity**, like tapping the foot or nodding the head. As Theorell (2014) said in his research on the physiological effects of listening to music, music listening has many effects on heart rate, heart rate variability, and hormones related to energy mobilization.

Furthermore, in Bernardi et al. (2006) research, the aim was to assess the potential clinical use of music to induce changes in the cardiovascular and respiratory systems. It was concluded that selecting the right music and alternating rhythms and pauses could induce relaxation and help in cardiovascular control. This study showed how music could affect heart rate, blood pressure, and respiration rate.

Video games can also affect various physiological responses even more when associated with music. As mentioned by Liljedahl (2011), individually, graphics and sounds provide different experiences, but complementing graphics with sounds can unravel new and unique experiences. Game designers might have opportunities to work with vision, hearing, other senses, and human abilities. With the union of sounds and other sensory inputs, the individual stimuli blend and become a new whole.

For example, games can increase **heart rate** and **blood pressure**, especially during intense or action-packed moments or during stressful or challenging parts. Some players also experience an

increase in **respiration rate** while playing and even show an increase in the levels of hormones such as **cortisol** and **adrenaline**. It is essential to notice that the type of game and the level of engagement and immersion of the player can influence these responses and can be altered by the existence of music.

However, as mentioned by Wöhrman and Ningalei (2018) in their studies of how sound affects player experience in a scenario of horror games by measuring heart rate and eye-tracking, it is hard to measure the impact and influence in a game, as measuring the exact impact of sound can differ from each player. Their conclusion indicates how the existence of subjectiveness on previous experiences of the player and factors such as personality and personal preferences can influence the responses generated, making it hard to measure the impact of sound in games. This situation might be one reason few studies are still exploring the area.

2.4 Influence of Music in Other Fields

The study of music and its impact on various aspects of the human experience has been a matter of interest for a long time in many applications, such as in cinema and medicine, and has been shown to have a substantial influence on physiological responses.

In this section, the applications and studies of the use of music in other fields will be analyzed and used to support the research on the relationship between music and player performance in games.

2.4.1 Music in Cinema

The use of music in cinema has a long history that has dramatically evolved. It could be seen since the early days of cinema, where live music was often performed to set the mood and provide a sense of excitement or drama. During the 1930s and 1940s, music played an increasingly important role in films, producing memorable songs to help advance the story and create a deeper emotional connection to the characters. This scenario can still be seen in the modern era, as music keeps evolving. Many films now feature elaborate soundtracks to enhance the story's emotional impact, creating memorable moments.

Although films rely mainly upon visual aspects to share a history, the soundtrack is an integral component that can contribute to the story's meaning. Boltz (2004). A technique often applied is using music parallel to a scene to improve or reduce the impact delivered to the audience. In her studies, Boltz also mentioned that music could bias the interpretation of visual elements. Furthermore, research revealed that when the soundtrack music was present, the audience would show stronger affective responses, altered interpretations, and improved memory of events. Boltz (2004).

As Klimmt et al. (2019) concluded, "soundtrack music clearly adds to and interacts with other cinematic elements in bringing about audience responses." In a model proposed by Cohen (2001), the congruence-associationist model (CAM) suggests that the associations that people activate when hearing soundtrack music can add and interact with The information received from other

elements in the film constructs the overall experience. Boltz (2004) confirmed this assumption of the CAM for film music in her research. Given so, Klimmt et al. (2019) considered that it could also be used to study the impact of music in games as a theoretical approach. Once more, the effect of music on video games is analyzed and shown to trigger or amplify specific emotions in players and create a sense of identification, characterization, and immersion, possibly enhancing a feeling of enjoyment and engagement in the player.

In conclusion, music in cinema plays an essential role in creating an emotional impact and atmosphere in a story and contributes to a viewer's immersive experience. Although music in games and the cinematic industry converge in many aspects, there is a principal difference: the interactivity between music and video games. As mentioned by Kestner (2016), "The major difference is that film does not change dynamically. The music is set to a specific point. In video games, the music must be dynamic, with the exception of cutscenes or cinematics."

2.4.2 Music in Medicine

The history of music's use in medicine dates back thousands of years. In ancient cultures such as Greece, Egypt, and China, music was believed to have therapeutic properties and was used in medical treatments. In the 20th century, music therapy became more formalized as a discipline and began to be used in mental health and rehabilitation settings. Music has a long and rich history in medicine and has evolved to become an essential and recognized form of treatment and a legitimate field of study. Music therapy is widely used to treat numerous conditions and is recognized as a valid and effective treatment.

Music can affect people in various ways, both physically and emotionally. Physically, listening to music can alter heart rate, blood pressure, and the release of certain hormones, such as cortisol, and increase the production of endorphins, which are natural pain relievers. Furthermore, music can alter mood, stress levels, and cognitive function by influencing the brain's neural activity.

Emotionally, it can improve overall well-being by conjuring up a wide range of emotions and memories and as a form of therapy to help with a wide range of issues, including anxiety, depression, post-traumatic stress disorder (PTSD), and even managing chronic pain. Additionally, it can boost creativity, promote relaxation, and enhance memory.

The study of music and its possible clinical applications and impacts have been increasing and have shown many results in different fields. For example, in Bernardi et al. (2006) research, it was concluded that music could induce arousal effects or focused attention, such as relaxing effects when slow or meditative, which could help manage cardiovascular disease. That is, it analyzed the use of music in modulating changes in the cardiovascular and respiratory systems and noticed changes in breathing rate, ventilation, blood pressure, and others that were mainly related to the tempo of the music.

Furthermore, in Novotney (2013) studies, it was mentioned how music could be used to treat pain and reduce stress. Listening to music could increase the body's production of the antibody immunoglobulin A and natural killer cells, boosting the immune system and reducing cortisol levels. It was also mentioned that music is used to soothe pediatric emergency room and palliative

care patients who showed relief from persistent pain when listening to it. Lastly, the research mentioned that they have been studying sound vibrations to help ease symptoms of Parkinson's disease, fibromyalgia, and depression.

In conclusion, more research is needed to understand the mechanisms by which music impacts human physiology fully. However, these findings can demonstrate the potential for music to play a valuable role in medical treatment and help ensure that patients receive the best care and improve the effectiveness of medical treatments.

2.5 Conclusion

While there is research concerning the applications and impact of music in games, there still needs to be more knowledge of how specific properties of music, such as tempo, pitch, and instrumentation, can affect the player's performance. Furthermore, it is possible to infer that studies in other fields, like cinema and medicine, can support and influence the research of music in games.

In the next chapter, a methodology will be proposed to design an approach to further study music's impact on player performance using physiological measurements.

Chapter 3

Crafting the Gameplay Experience: Design and Music

As analyzed in Chapter 2, there still needs to be more knowledge of how specific properties of music can affect the player's performance. Thus, this thesis will use physiological measurements of users, aiming to develop a relationship between music parameters and player performance and answer the questions established in the introduction chapter.

This chapter will determine a methodology to design a possible approach to measure how music can impact player performance using physiological measurements. The approach shall consider aspects such as:

- **Music Parameters**: the choice of the parameters that will be used to create variations of music characteristics, like tempo.
- **Compositions**: details about the compositions. How many were created, which parameters varied in each one, duration, and other relevant characteristics.
- **Game Design and Development**: Information regarding what the game consisted of and what aspects were considered to design it. The elements that should be noted are mechanics, aesthetics, story, and technology, as mentioned by the **Tetrad Framework** for game design, developed by Schell (2008).
- **Testing**: As this study lays heavily on user measurements and performance analysis, the testing phase is crucial to the work. Therefore, some of the elements that should be explained are regarding the survey answered by testers, and making the procedure, questions, and measurements used clear. Furthermore, information about the users should also be assessed, always considering the confidentiality of the user's data.
- **Physiological Measurements**: Information regarding what physiological responses will be measured during the test, what devices will be used to do so, and how they work.
- **Limitations**: Aspects or situations that could cause a negative impact or serve as constraints to further development.

3.1 Methodology

The methodology will be reported in this section, although the details of each phase and aspects will be further explained in the following sections.

This work is a heavily testing-based study, so all elements necessary should be complete and standardized before proceeding to tests.

The development process started after defining state-of-the-art and acquiring further knowledge of the field with the literature review. The main steps were producing the compositions, designing and developing the game, promoting the tests, and analyzing the results. The parameters used and analyzed were formally defined to start producing the compositions, as they are the guide and the control group to produce the pieces. As soon as they were decided, the production phase began.

Concurrently with music production, the game concept was established and designed after deciding on genre, technology, etc. As the game level to be used for testing is a crucial part of the work, it was intensely tested to ensure no issues, such as bugs, that could impact the gameplay and the player's overall experience.

The testing began after the game, and the compositions were appropriately finished and consistent. The process started by defining and creating the form that testers should answer before and after playing the game, including essential demographic topics. Opinions and observations regarding each gameplay should be asked after each phase, and a conclusion section should be answered after playing all versions.

When promoting the tests, the user initially answered the form with personal questions like gender and age. Afterward, testers should play three game versions once while the physiological responses are measured and recorded. In addition to the physiological measurements, different performance variables were recorded, such as the duration of each game and the number of tries, which will be further described.

After playing the three different versions, users would answer a few more questions about the overall experience. After the testing phase, the results were analyzed. Each composition variable and physiological measurement were analyzed individually and associated, as well as other registered performance variables, and finally, conclusions were drawn from the results obtained.

3.2 Requirements and Pre-requisites

Several requirements and pre-requisites were considered during the game development to achieve the research objectives of evaluating the impact of music characteristics on player performance and experience.

Each game level needed to strike a balance between providing an engaging challenge and avoiding excessive difficulty that could hinder player performance or enjoyment.

Furthermore, the game level should be designed to focus on user-friendliness, providing an intuitive interface and controls, ensuring that participants can easily interact with the game mechanics and navigate through the gameplay elements. Also, it should contain information to help the player, such as a life bar and the number of enemies in the level.

Another crucial aspect was using high-quality assets to create a visually appealing environment that enhanced immersion and player engagement. Careful consideration was given to selecting visually appealing graphics, animations, and textures that contributed to a captivating atmosphere within the game level.

Lastly, ensuring the absence of bugs in the game was another essential requirement during the development process. A rigorous testing approach was used to identify and resolve any issues that could affect the gameplay experience or data collection.

Those essential aspects should be considered in the design and development phases. These considerations contribute to a better game, creating a more enjoyable and successful gaming experience.

3.3 Game Concept and Design

In this section, the concept and overall design of the game will be explained and detailed, as well as the implemented mechanics.

The first step of the development process was to define the theme and concept, serving as the game's vision and making it easier to decide on other aspects of the game. After analyzing the availability of 3D assets in the Unity asset store, it was decided that the game would have a 3D dimensionality to provide players with increased immersion.

With the dimensionality set, the game concept began to be developed, drawing inspiration from the assets chosen. The selection of a warrior as the main character and including orcs as enemies inspired the medieval aesthetic that would further be selected as the game's central concept. Each game version was developed with a distinct ambiance and vibe to create an outstanding gaming experience and promote diversity and originality. To achieve this, a key aspect in establishing the unique atmosphere of each version was the implementation of diverse Skybox assets, which encompass the virtual sky surrounding players as they navigate through the game world.

After establishing the game's concept, the next step was developing it. Aiming to provide intuitive and familiar controls, the decision was to incorporate typically used input methods. Players would navigate the game world by utilizing the keys A, W, S, and D, which allowed moving in different directions. The space bar was used to execute jumps, enabling players to overcome some obstacles. The mouse's left button was assigned as the attack command and controlled the camera. Using familiar controls aimed to minimize the learning curve, allowing players to quickly adapt and focus on the game world.

Figures 3.1 and 3.2 are versions 4 and 5 from the game and shows the difference in atmosphere and vibe.

Figure 3.1: Game's Version 4

Figure 3.2: Game's Version 5

3.4 Music Composition and Integration

In this section, the process of creating the musical compositions specifically tailored to the game will be explained, as well as the chosen variables and the integration in the game. The songs were produced using the Reaper Digital Audio Workstation (DAW).

A total of six compositions were produced, each adhering to a consistent pattern while adapting to two distinct variables: tempo and tonality.

The compositions revolved around three distinct tempo variations: slow, medium, and fast. Furthermore, the compositions were shaped by two tonality variations: major and minor. Those variations will be explained in the following sections.

Considering those parameters and their respective variations, there were the following possibilities for compositions:

Table 3.1: Characteristics of each Version

Versions	Tempo	Tonality	Acronym
1	Fast	Major	Fast-Maj
2	Medium	Major	Med-Maj
3	Slow	Major	Slow-Maj
4	Fast	Minor	Fast-Min
5	Medium	Minor	Med-Min
6	Slow	Minor	Slow-Min

3.4.1 Musical Theme and Concept

After the theme and aesthetics of the game were determined, the overall vibe and concept of the music were easily defined. It was imperative to ensure that the music seamlessly complemented the gameplay experience and effectively conveyed the intended emotions and atmosphere of the game.

To better follow the medieval theme of the game, it was decided that the music would follow an epic and orchestral vibe and atmosphere to align with the setting and the desired emotional impact on players. This approach aimed to transport players into a rich and captivating world that resonated with the game's medieval theme. The idea was to create a sense of heroism, and adventure, strengthening the overall intensity and impact of the gameplay.

3.4.2 Music Composition, Structure, and Dynamics

Following the concept defined for the music, the next step would be to pay attention to musical elements such as instrumentation, harmonies, and arrangements, so the compositions would be crafted to reflect the spirit of medieval times while incorporating modern production techniques.

The compositions featured diverse instruments to create an immersive musical experience. The instrumental ensemble consisted of carefully selected elements, including drums, cello, piano, three distinct tracks of violin variations, and the ethereal voices of a choir. Each instrument was thoughtfully chosen to evoke the desired atmosphere and capture the essence of the game. The six songs followed the same structure, only altering the tempo (BPM), notes, and chords to adapt to the correct tonality.

Overall, the decision to pursue an orchestral musical direction aimed to create a cohesive and immersive experience for the player. Aligning the music with the game's medieval theme

and desired emotional impact, the compositions could enrich the aesthetic and contribute to the player's journey through the gameplay.

3.4.2.1 Music Tempo

The first experimental variable focused on was the tempo of the music. It was manipulated to create three distinct conditions: slow, medium, and fast. These tempo distinctions were marked by carefully selected beats per minute (BPM), with 80 BPM for a slower pace, 100 BPM as the medium beat, and 140 BPM for a faster tempo.

As mentioned, the chosen DAW was Reaper, which made it easier to change the tempo of each composition, so it consisted of mainly altering the BPM field after finishing the production.

3.4.2.2 Music Tonality

The second variable selected was tonality, encompassing two options: major and minor. The major tonality was represented by a C key, while the minor tonality was embodied by a Cm (C minor) key.

In the composition version featuring a major key, among other elements, a chord progression of C, G, F#, and F was incorporated. This progression blends major and chromatic elements, creating a harmonic nature. The C, G, and F chords follow the well-known I-V-IV progression in the key of C major, a frequently utilized progression in music. However, the progression takes an unexpected twist by adding the F# chord. This chord does not originally belongs to the C major key, which introduces a chromatic alteration. Consequently, it creates a distinctive harmonic color to the composition.

On the other hand, the compositions in the minor tonality revolved around the key of C minor. Some of the chords employed in these compositions were Cm, Gm, Am, and Fm, along with some other chords that follow the C minor scale. These chords are derived from the notes of the C minor scale, resulting in a harmonically coherent sequence within the key of C minor. This progression in C minor typically evokes emotions of intensity and melancholy. The Cm chord is the tonic chord of the key, establishing the minor tonality.

3.5 Implementation details

The game was developed using Unity, a renowned and extensively employed game development engine that leverages the power of C# programming language. Unity proved valuable, providing access to an expansive asset store that facilitated the implementation process. The Unity asset store sourced key elements such as the main character, enemies, and various architectural assets. This utilization of the asset store significantly simplified some aspects of the development process, ensuring a better gameplay experience.

As mentioned before, the game used familiar controls, navigating the game world by utilizing the keys A, W, S, and D and the space bar to execute jumps. The mouse's left button was used as the attack command and controlled the player camera.

Furthermore, the main character and the enemies had established animations for each available action, such as walking, running, attacking, and dying. Each action was implemented to enhance the gameplay's visual appeal and the player's immersion. Regarding the combat system, the choice was made to keep it straightforward, so the player had only one means of attacking, using the mouse's left button. For the attack to be successful, the character had to be close to the enemy. In addition, the player had a health bar displayed on the screen. Every attack from the player against an enemy would strike a 20-point damage. The player and the enemy had a maximum of 100 life points. If the player reached 0 points of life, he would lose and have to retry the level. The level would be concluded when the player reached the checkpoint, which was the same place in each version and marked by an arc with flags, to make it easier for the player to acknowledge it as the end.

Leveraging Unity features, the Nav Mesh agent was employed in the game. This tool granted the enemies intelligence and autonomy, enabling them to navigate the game's environment with precision and awareness. The enemies were programmed using a state machine with three possible states: patrol, chase, and attack, each serving a specific purpose in shaping the enemy's actions and responses.

The default state of the enemy was the patrol state, where it covered a predetermined radius, scanning its surroundings for the player's presence. However, the enemy's state shifted when the player reached a specific proximity. The enemy transitioned into the chase state when sensing the player, aiming to close the distance and reach its target. As soon as the enemy got close to the player, it would change to the attack state. In this state, it would start unleashing attacks against the player every few seconds, offering a reaction time. Every successful attack from the enemy took 10 points from the player's life bar. If the player managed to create sufficient distance between themselves and the enemy, surpassing a determined threshold, the enemy would return to its patrolling state. The enemies' damage power was lower to give the player a better chance to win, as many enemies existed throughout the level.

3.5.1 Graphic Interface

The game's flow was structured to provide a seamless user experience. It started with the main menu, presenting players with various alternative gameplay options (this topic will be further explained in the following sections). Once selected, the game transitioned to a waiting scene, where players could initiate the level whenever they were ready.

Figure 3.3: Game's Main Menu

Figure 3.4: Game's Waiting Menu

Additionally, there were two scenes when the game was over, either when it was won or lost, containing information from the gameplay, such as the time to conclude the level, the accuracy of the hits, and the final health of the player.

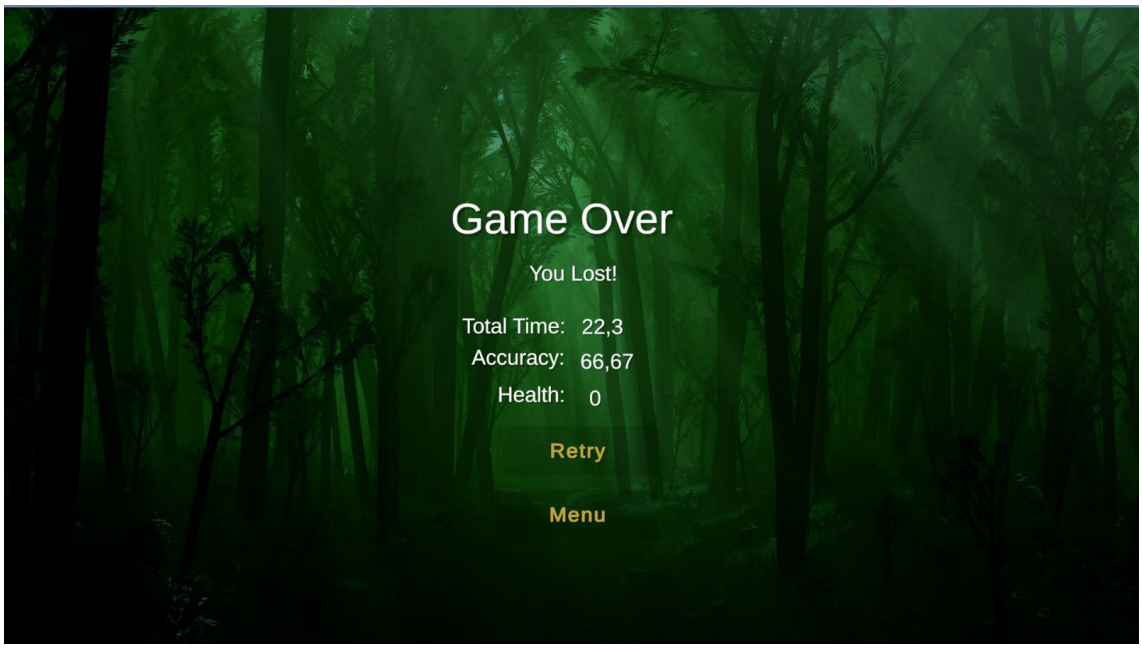

Figure 3.5: Scene When a Level is Lost

Figure 3.6: Scene When a Level is Concluded

The game featured a designed graphic interface to provide information to the player. This interface contained elements such as a timer and the player's health bar.

The timer shows the current elapsed time in the top right corner and stops when the level is concluded or paused when the pause menu is opened.

Furthermore, players were constantly informed of the number of remaining enemies in the level in the top left corner, enabling them to measure progress and strategize accordingly. The

player's health bar allows them to monitor their well-being and make decisions during combat and appears in the bottom left corner. Equally important, each enemy had its health bar above them, allowing players to assess the effectiveness of their attacks and decide their next step.

Figure 3.7: Example of the Graphic Interface

Lastly, the game also offers a pause feature accessible through the ESC key, which lets players return to the main menu.

Figure 3.8: Pause Menu

3.6 Conclusion

This chapter provides a comprehensive overview of the research methodology employed in the study. It explores the details of game development, encompassing the conceptualization, design, and implementation aspects. The gameplay mechanics are also meticulously described. Moreover, it details the process behind the music compositions tailored for the game. It offers insights into their structure, dynamics, and choices regarding tempo and tonality parameters.

The subsequent chapter will focus on the testing process and present the results obtained.

Chapter 4

Validation and Results

4.1 Experimental Setup, Protocol and Equipment

This section describes the details of the experimental setup and procedures employed in this research. The following subsections examine the various aspects of the experimental design, including participant recruitment, equipment utilized, and the protocol followed during the study.

To initiate the testing phase, it was essential to have the game fully developed and the music integrated. Additionally, the measurement of participants' physiological responses required the use of specialized equipment. For this purpose, a *BITalino* [1] device was employed, which is a biosignals platform designed explicitly for Education and Prototyping. The board utilized in the study was equipped with three sensors, namely *electromyography* (EMG) for muscle activity, *electrocardiography* (ECG) for heart activity, and *electrodermal activity* (EDA) for skin conductance. These sensors allowed to collect the data related to participants' physiological responses during gameplay. An application called *OpenSignals*[2], compatible with the board, was used to enable data visualization and recording.

The experimental setup encompassed a few essential components to enable the testing process. These included a computer, a BITalino device, a mouse, and a set of headphones.

The tests were structured so that each participant played a subset of three of the six available game versions to ensure a balanced and manageable testing process. The order of the versions within each alternative was arranged to minimize potential bias or sequence effects. The distribution of versions across the alternatives was as shown in table 4.1:

[1] https://support.pluxbiosignals.com/article-categories/bitalino/
[2] https://support.pluxbiosignals.com/article-categories/opensignals/

Table 4.1: Separation of version into alternatives

Alternatives	Versions
A	1, 2, 3
B	2, 3, 4
C	3, 4, 5
D	4, 5, 6
E	5, 6, 1
F	6, 1, 2

The selection of playing only three versions for each participant was based on feedback acquired during a pilot test, where participants expressed concerns that playing all six versions with similar overall levels could lead to tiredness and boredom, potentially compromising the quality of their responses and engagement. And testing the effect of subtle variations with such a long sequence that can cause imprinting.

The testing protocol began with an introduction to enlighten participants about the study's purpose and provide an overview of the experimental procedure. Next, participants would fill the questionnaire with demographic information and relevant background details that might influence their responses and gather interesting insights. After completing the questionnaire's fundamental questions, participants were introduced to the game interface and provided clear instructions on navigating, interacting with the game environment, and performing specific actions. Lastly, participants were instructed and attached with the proper placement of the electrodes for EMG, ECG, and EDA measurements according to established guidelines from the manufacturer's documentation [3], such as the images below.

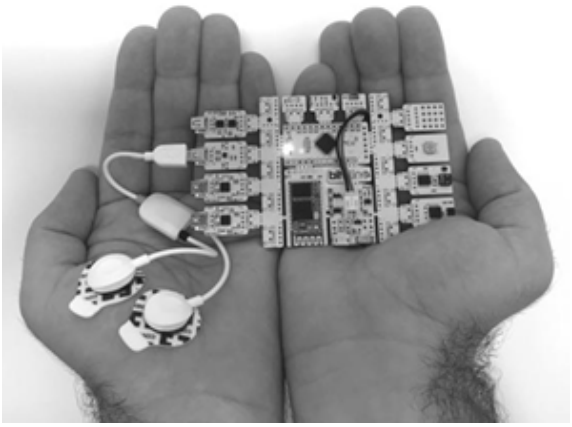

Figure 4.1: EDA Electrodes Placement

[3] https://support.pluxbiosignals.com/knowledge-base/bitalino-documentation/

Figure 4.2: ECG Electrodes Placement

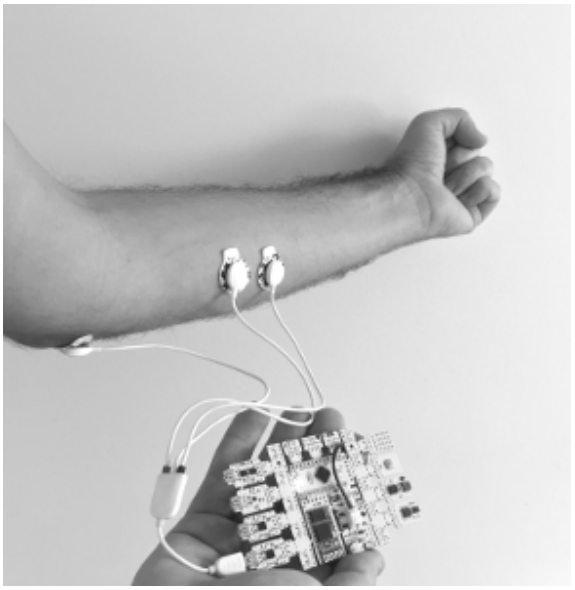

Figure 4.3: EMG Electrodes Placement

The electrodes were positioned on the right forearm for the EMG measurements to capture the muscle activity involved in controlling the attacks. The electrode placement followed the same arrangement as depicted in the provided image. Regarding the EDA measurements, the electrodes were positioned on the right hand. Due to the relatively short length of the EDA sensor, the right hand provided a better fit for accurate readings, considering the other sensors' position. The ECG sensors followed the exact placement as in the image.

After attaching the electrodes and starting the recording in the OpenSignal software, the alternative the user would play, which was previously assigned, was selected in the main menu of the game, and the player would be taken to the waiting scene, where they would start the level

whenever they were ready to start. If the player fails to conclude the level on the first try, they should play again until success.

Once each phase was concluded successfully, the player would answer some questions regarding the versions they had just played. This process would repeat after each phase finished. Lastly, the recording of the physiological measurements would be stopped, and the users would be asked to provide subjective feedback and complete a post-experiment questionnaire to gather their perceptions, opinions, and overall experience with the game and its music.

4.1.1 Participant Recruitment and Selection

This section focuses on describing the process of recruiting and selecting participants for the study. The primary approach utilized for participant recruitment included academic channels. Through this method, many participants shared similar educational backgrounds and a close range of ages. However, it is noteworthy that the sample exhibited more diversity in terms of gender but mainly in the gaming experience, contributing to a more representative dataset. It is also important to note that there were not any restrictions on participation.

One of the notable challenges encountered during the participant recruitment process was the requirement for in-person testing. It posed some difficulties in coordinating participant availability.

A total of 24 individuals participated in the testing process. This number was chosen as having a multiplicative factor of six was desirable, ensuring that all alternatives within the game were tested consistently across participants. Consequently, each game version was played twelve times. In the images below, there is the distribution of age and gender of the participants.

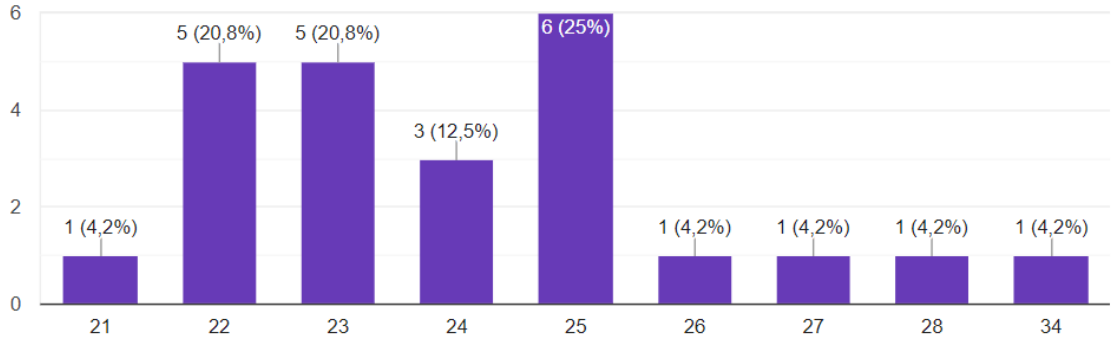

Figure 4.4: Participants Age

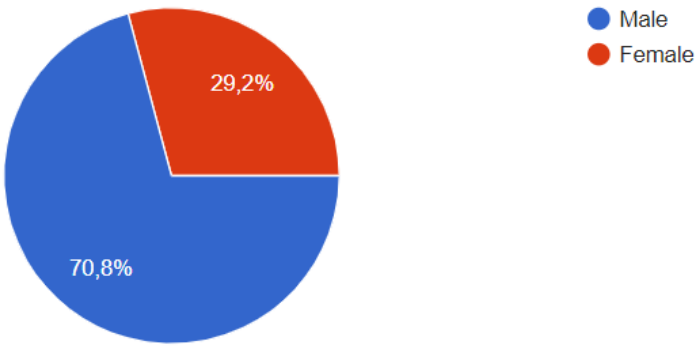

Figure 4.5: Participants Gender

Upon analyzing the collected data, it was observed that the average age of the participants was 24.3 years, ranging from 21 to 34 years old, with a median of 24 years. The gender distribution among the participants revealed seven females and seventeen males out of the total sample size.

Furthermore, the diverse range of participants' gaming frequency was an interesting observation. The distribution encompassed individuals with varying gaming involvement, as depicted in the graphic below. The Likert Scale was used to capture participants' self-reported gaming frequency, ranging from 1 (never) to 5 (always).

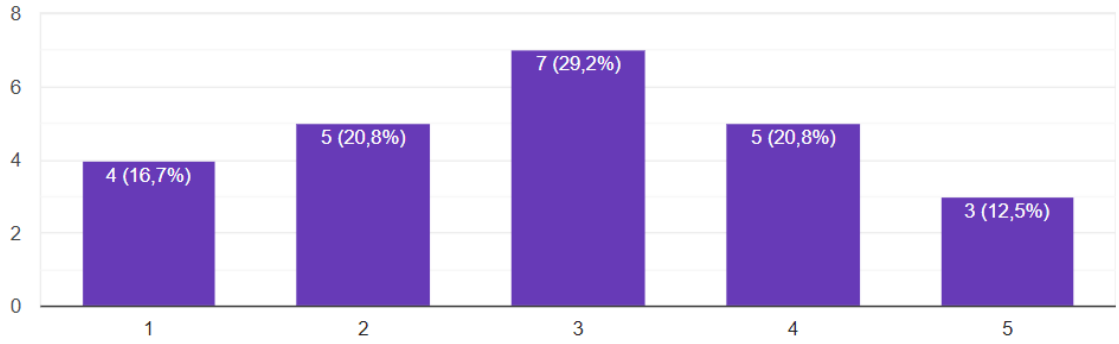

Figure 4.6: How often participants play video games

After analyzing the graph, it was possible to notice an average of 2.9 and a median of 3. Thus, this value shows that most participants had at least some experience with gaming.

The next question of the form was what genres of video games the users typically enjoy, and involved a few options and an open field for other values. The most played genre chosen was adventure/action, followed by Open World games, RPG, and FPS (first-person shooter). After seeing these results, it confirmed that the choice for the game genre was a good fit, as it matched well with the participant's taste.

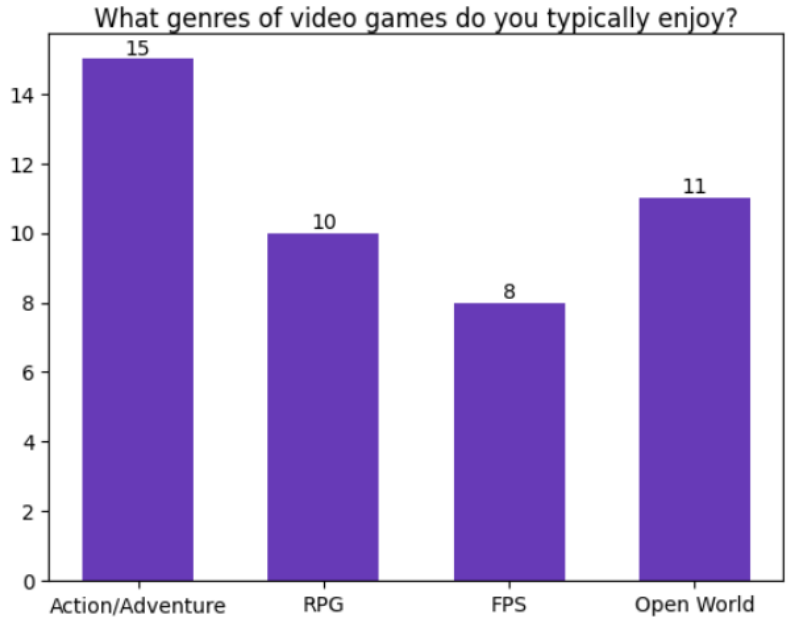

Figure 4.7: What genres of video games participants typically enjoy

4.2 Questionnaire Results

This section is dedicated to presenting and analyzing the answers and results of the questionnaire applied during testing. As mentioned, a total of 24 questionnaires were obtained. The form was divided into a few sections, aiming to make it clear for the player at the questions will revolve around.

The first was the General Information regarding the player, described in section 4.1.1.

The following section in the form is related to the Gaming and Music Experience. It encompasses additional subsections that will be described in detail below.

Next, the questions regarding each version played are reported and answered following each level played.

The last section is a conclusion section, with questions about all the levels played.

The questions ranged from multiple choice to Likert scale questions and a few open answers.

4.2.1 Gaming and Music Experience

This section was divided into the following categories:

1. Gaming Experience
2. Music Preferences
3. Perception of Music

The Gaming Experience subsection included the questions mentioned in the previous chapter: "How frequently do you play video games?" and "What genres do you typically enjoy?".

Following, participants were asked about their perception of the impact of music on the gaming experience. The responses indicated a strong consensus, with nearly all participants agreeing that music significantly influences game perception to some degree. The chart in figure 4.8 illustrates this agreement, with an average rating of 4.5 and a median of 5. These findings highlight the participants' understanding of music's role in shaping gaming experiences. These overall results will be thoroughly analyzed during the analysis section.

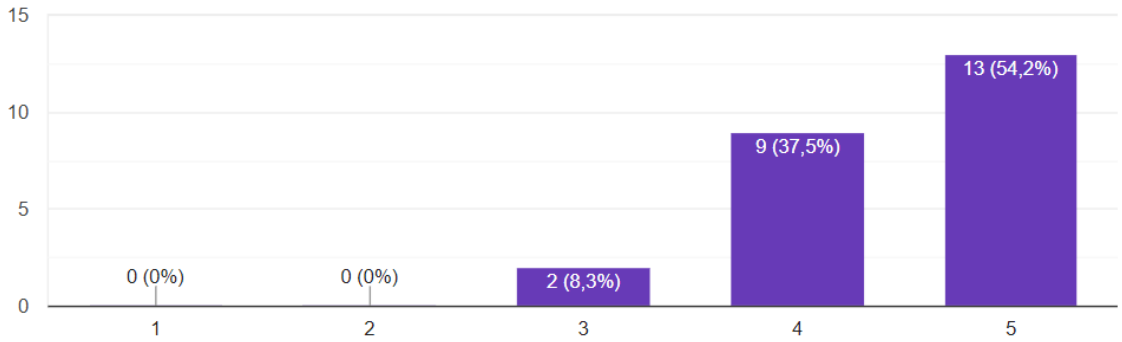

Figure 4.8: Can music impact in your perception of the game?

The next question was if there were any games in which the soundtrack or sound effects stood to them or had a significant impact on their gameplay experience. The responses revealed several noteworthy titles, with some games mentioned multiple times, such as Minecraft, Dark Souls, and Destiny. They all stood out as games that have received high recognition for their soundtracks, effectively enhancing the overall gameplay experience. Additionally, other highly acclaimed titles such as Skyrim, The Witcher 3, Red Dead Redemption 2, and The Last of Us were also mentioned, highlighting the praise they have received for their sound design.

Afterward, the Music perception section began and consisted of the three following questions, with the first two answers being a Likert scale and the last one, an open answer:

- How important is music in your gaming experience?
- How often do you typically listen to music while playing video games? That is, music that does not belong to the game
- What genre of music do you usually listen to when playing games?

The participant's responses to the first question showed a strong consensus. The scale ranged from 1 (Not important) to 5 (Indispensable). The chart in figure 4.9 indicated that music played a significant role in their gaming experience, with an average rating and median of 4.

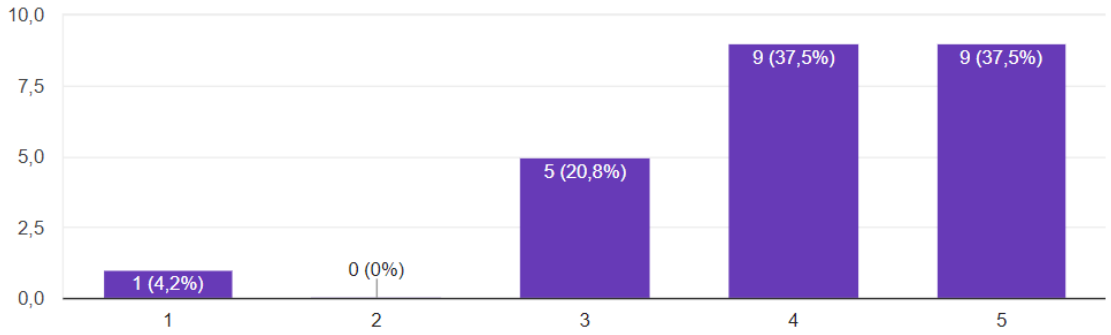

Figure 4.9: Importance of music in gaming experience

Regarding the second question, the scale ranged from 1 (never) to 5 (always), and most participants indicated that they do not frequently listen to music unrelated to the game while playing. Instead, they tend to focus on the in-game soundtrack, as the chart in figure 4.10 indicates. It was reported an average of 2.6 and a median of 2

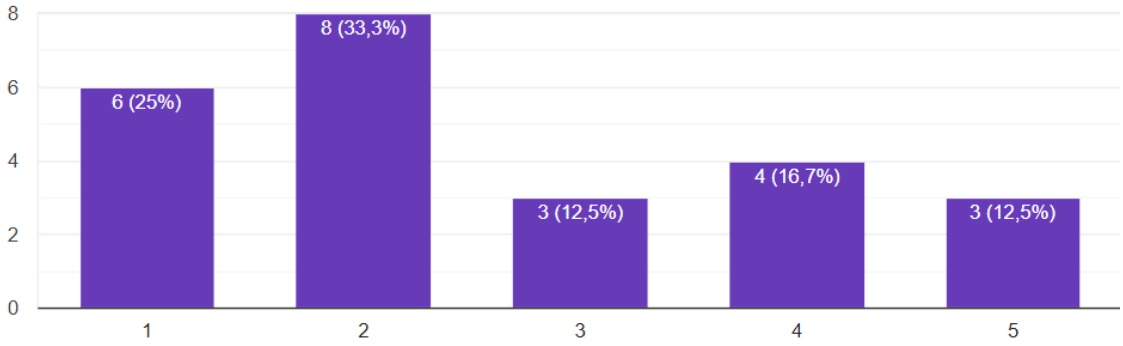

Figure 4.10: How often do you typically listen to music while playing video games?

The third question allowed participants to specify the genre of music they typically listen to while gaming. The responses encompassed a diverse range of genres, including metal, jazz, rock, rap, indie rock, lo-fi, pop, and synthwave. Thus, it demonstrates the wide variety of musical preferences among gamers.

Lastly, the Perception of Music section started, which included questions about the impact of music on the participant's emotions and physiological responses, as well as the influence on the gaming performance or engagement. The questions consisted of a Likert Scale and are detailed below.

- Are you generally sensitive to the emotional impact of music (e.g., changes in mood)?
- Have you ever noticed physiological responses (e.g., increased heart rate) while listening to music?

- Do you think the characteristics of music can influence your gaming performance or engagement?

The first question provided a range of options from 1 (Not at all) to 5 (Extremely). The results showed a more varied distribution, as depicted in the chart in figure 4.11, with an average rating of 3.8. However, the median of 4 indicates that a significant proportion of participants are typically sensitive to the emotional impact of music.

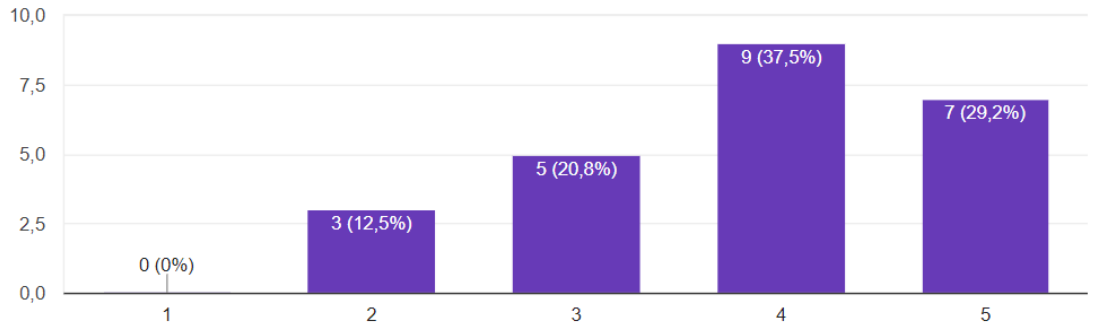

Figure 4.11: Are you generally sensitive to the emotional impact of music?

For the second question, options ranged from 1 (Never) to 5 (Always). In comparison to the previous question, the results displayed a slightly lower average of 3.7 and a median of 3.5, suggesting that while participants may be sensitive to the emotional impact of music, they notice physiological responses to a lesser extent.

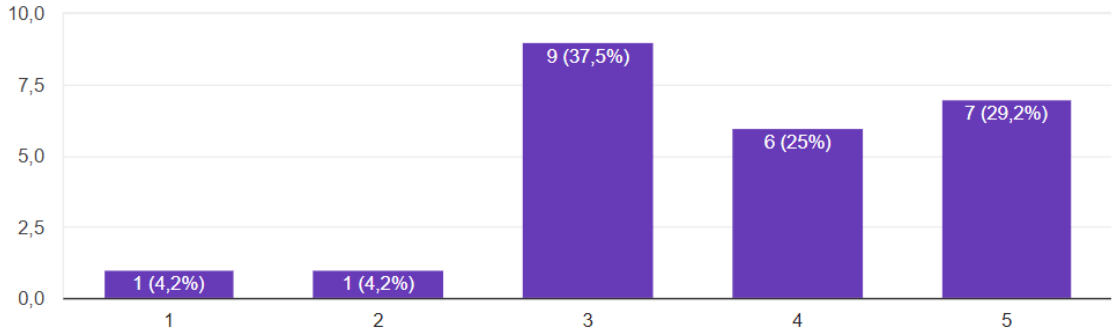

Figure 4.12: Have you ever noticed physiological responses while listening to music?

The last question also used a scale from 1 (Not at all) to 5 (Extremely). It revealed an average rating of 4.1 and a median of 4, indicating that most participants agree and acknowledge the potential influence of different aspects of music on their gaming performance or engagement.

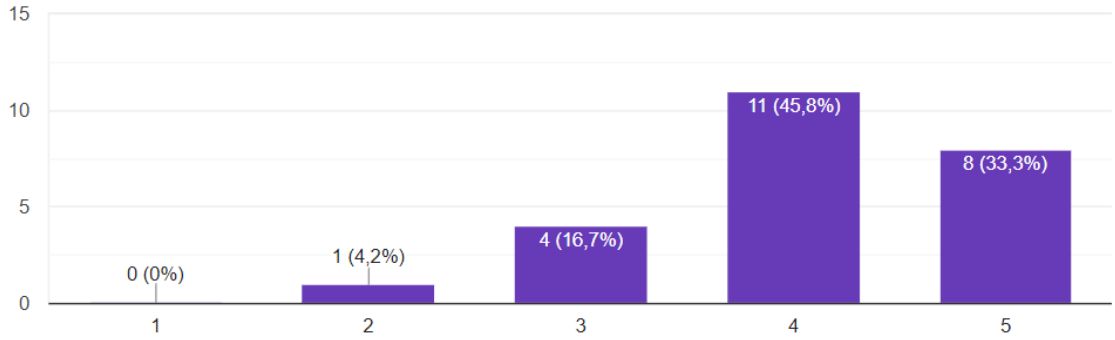

Figure 4.13: Do you think the characteristics of music can influence your gaming performance or engagement?

In conclusion, the findings indicate that participants generally consider music necessary in their gaming experience, significantly impacting their emotions and perceived gaming performance or engagement. The participants reported sensitivity to the emotional impact of music, although noticing physiological responses were less common, as noticed in the figure 4.12. Overall, the questionnaire provided valuable insights into the participants' perspectives on the role of music in gaming. In the table 4.2, there is a summary of the results from all questions.

Table 4.2: Summary of Questionnaire Results

Question	**Average**	**Median**
How frequently do you play video games?	2.9	3
Do you think music can impact your perception of the game?	4.5	5
How important is music in your gaming experience?	4	4
How often do you typically listen to music while playing video games?	2.6	2
Are you generally sensitive to the emotional impact of music?	3.8	4
Have you ever noticed physiological responses while listening to music?	3.7	3.5
Can characteristics of music influence your gaming performance or engagement?	4.1	4

4.2.2 Versions Played Section

In this form section, participants played a level and provided feedback by answering questions about that level. This process was repeated for each version played. The questions remained the same across all versions to ensure reliable and comparable data for analysis. The subsequent subsections will provide further details regarding the feedback received for each version and the respective data analysis. The participants answered the following questions on a Likert scale ranging from 1 to 5 for each version played:

- How would you rate the suitability of the music in this version for the gameplay?
- Did the tempo (speed) of the music in this version match the gameplay pace?
- Did the mood or tone of the music in this version align with the game's atmosphere?

- How well did the music in this version contribute to the overall immersion in the game?

Furthermore, an analysis will be performed on the performance variables, including the time taken to complete the level, the accuracy of hits, final health, and the number of tries for each game version. The time to conclude the level indicates the players' speed and efficiency in completing each version. At the same time, the accuracy of hits measures the players' precision and ability to target and engage with the enemies accurately. The final health status showed the players' ability to manage the character throughout the gameplay. Lastly, the number of tries demonstrates the players' adaptability or difficulty in overcoming each version.

4.2.2.1 Version 1

As mentioned, this version of the game had a composition with a major tone and a fast tempo. The participants who played this version consistently described experiencing a sense of tension and pressure during gameplay. Furthermore, they reported that the song matched the level's visuals, and the fast tempo helped in the immersion and urged a feeling of battle and excitement. The specific results of each question are represented in the following charts.

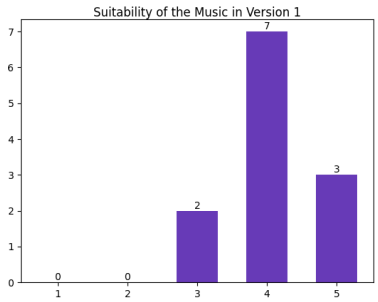

Figure 4.14: Suitability of the music in Version 1

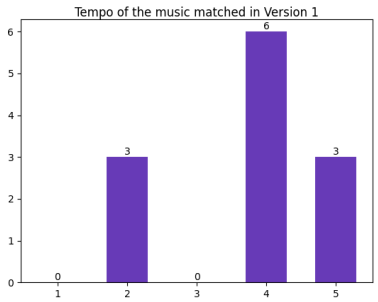

Figure 4.15: Tempo matched the gameplay pace in Version 1

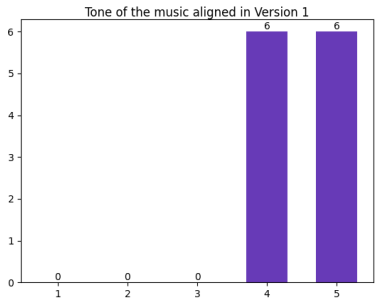

Figure 4.16: Tone of the music version aligns with the game in Version 1

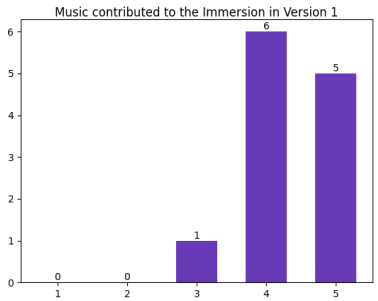

Figure 4.17: How music contributes to the immersion in Version 1

According to the data, the suitability of the music for the gameplay received an average rating of 4.1, indicating a positive response from the players. The tempo of the music in this version

had an average rating of 3.8. Furthermore, the tone of the music received a high average rating of 4.5. In terms of immersion, the music in Version 1 was reported to contribute significantly, with an average rating of 4.3. This high value seems to indicate that the music made players feel more engaged and immersed in the game, as it was also mentioned in the open feedback from participants.

Overall, the questionnaire results for this version were considerably high compared to the other versions, as it will be shown later.

Regarding the performance variables, the average time to conclude this version was 67,08 seconds, one of the fastest times out of all versions. This value might indicate that a faster tempo influences the performance, as this version was the one with the highest music tempo value.

The accuracy of hits of this version reported an average of 21.91%, the lowest value out of all levels. This low value could have happened because almost all of the participants that played this level did not try a single hit, ending up with an accuracy rate of 0, even though the overall accuracy of hits in the level was also considerably low, with a standard deviation of 22.50 and an amplitude of 53.33.

The average final health of the participants in this version was also one of the highest, with a rating of 62.50. This record could be related to the fact that it was the fastest level to be concluded. The players did not engage in much fighting as they rushed to finish, therefore not losing a lot of health from combat damage.

Lastly, for the number of tries, the highest number of attempts was 3. However, this was a minority of the values, as this variable showed a median of 1 and an average rating of 1.42. In addition, the two participants who took three tries to finish had this version as the first one they played so that it could reflect the learning curve of the game.

Table 4.3: Summary of performance variables in Version 1

V1	**Time**	**Accuracy**	**Health**	**Tries**
Average	67,08	21,91	62,50	1,42
Standard Deviation	50,96	22,50	32,79	0,79
Amplitude	147,60	53,33	80,00	2,00
Median	49,7	17,26	60	1

4.2.2.2 Version 2

This version had a composition with a major tone and a medium tempo. The participants for this version reported a high feeling of tension more often than those for version 1. Furthermore, pressure, suspense, and apprehension were used to describe this version. Many players who played versions 1 and 2 could feel the difference in tempo. Most participants reported that this tempo matched the best mechanic of 'hit and dodge,' and the game and the music were synchronized, making the gameplay easier. However, a few players did mention that they felt it was too slow and could be more exciting. This feedback might indicate that the medium tempo created a more

dangerous atmosphere, making the players feel more nervous and, therefore, more immersed. However, for some, it seemed too slow and not as well fitting.

The ratings acquired for this version showed a lower average rating than others. Regarding the suitability of the music for the gameplay, it was reported an average rating of 3.8, which was the lowest rating but not the only version with it. The average rating for the tempo and the tone of the music alignment with the game's atmosphere was the same, with 3.6. Lastly, regarding how well the music contributed to the immersion in the game, it showed an average rating of 3.9. The complete data are shown in the charts of figures 4.18, 4.19, 4.20, and 4.21 .

Overall, this version's rating was a bit lower than the others.

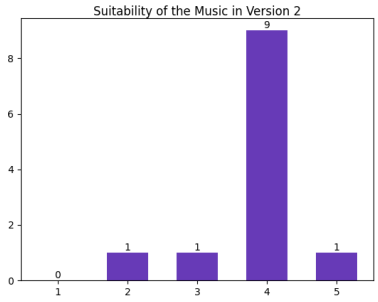

Figure 4.18: Suitability of the music in Version 2

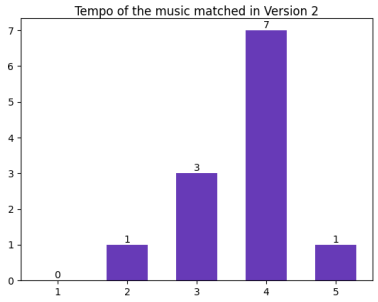

Figure 4.19: Tempo matched the gameplay pace in Version 2

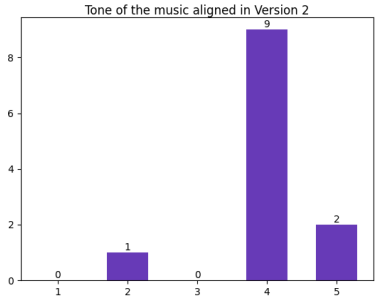

Figure 4.20: Tone of the music version aligns with the game in Version 2

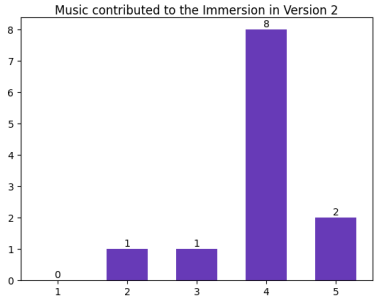

Figure 4.21: How music contributes to the immersion in Version 2

Considering the performance variables, the average time of conclusion for this version was 91.39 seconds, a value higher than version 1 but not the highest overall.

The accuracy of hits showed an average of 64.93%, the highest average rating of all versions. Because of the slightly slower tempo, the players were more cautious when attacking, trying to dodge the attacks more and in less rush to conclude the level. This way of playing was also reflected in the average rating of the player's health, which was also the highest of all levels, with a total of 66.67, showing that participants were indeed more cautious and tried to dodge instead of only attacking and taking hits.

Table 4.4: Summary of performance variables in Version 2

V2	**Time**	**Accuracy**	**Health**	**Tries**
Average	91,39	64,93	66,67	1,00
Standard Deviation	58,81	34,85	30,55	0,00
Amplitude	193,00	100,00	90,00	0,00
Median	75,6	78,46	75	1

Something unique about this version is that it was the only one that all participants only needed one try to conclude the level. The summary of the results for this version is shown in table 4.4.

4.2.2.3 Version 3

This version was a maze with a major tone and slow tempo composition. The reactions to this version were majority positive, where many participants reported enjoying the level, and the emotions the music instigated matched the suspense vibe. It increased the feeling of being lost and disoriented, which helped in the immersion. They also described feeling a lot of tension, pressure, and fear, which were the idea of combining the maze with a slower song. Out of the twelve participants that played this version, only one said they wished the music was faster, and the rest agreed that the slower tempo fitted precisely with the maze concept, making them more immersed.

Regarding the data from the questionnaire for this version, it received considerably high average ratings. For the suitability of the music for the gameplay, it had an average of 4.2, which was the highest value for suitability among all versions. The match between the tempo and the gameplay pace showed an average of 3.8, the lowest rating for this version, as few participants wished for faster music.

For the alignment of the tone of the music with the atmosphere, it was reported positive ratings, with an average of 4.3. Lastly, It also showed a positive rating regarding how the music contributed to the immersion, with an average of 4.1.

Overall, this version showed positive results and feedback from the participants, with most of them enjoying the level combination, the feelings brought by the music, and a good amount of immersion.

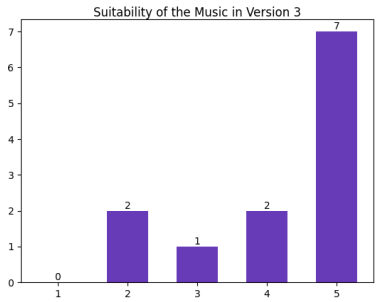

Figure 4.22: Suitability of the music in Version 3

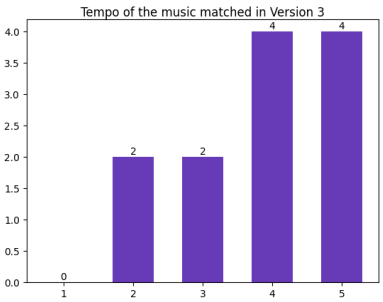

Figure 4.23: Tempo matched the gameplay pace in Version 3

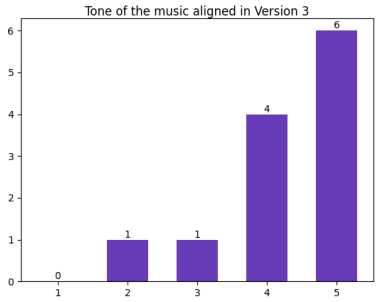

Figure 4.24: Tone of the music version aligns with the game in Version 3

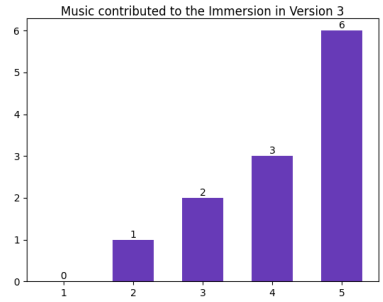

Figure 4.25: How music contributes to the immersion in Version 3

For the performance variables, it was expected that the versions with a maze would take more time to conclude, which indeed happened. This version had an average conclusion time of 152.93 seconds, the highest conclusion time. It was also the version with the greatest standard deviation, of 79.40, representing that it was the version with the most variation for time, where some participants had a time around 60 to 80 seconds while others took more than 200 seconds to finish, contributing to this higher standard deviation.

The accuracy of hits in this version was not very high, with an average of 41.41. This value could be explained for a similar reason to version 1. Almost half of the participants avoided confrontations and had an accuracy of 0. Furthermore, the maze might have made it harder for the player to aim correctly, lowering the accuracy of hits.

The average final health for both versions with the maze was lower. This version showed an average of 45.83. This low value could have happened because the player avoided confrontation or had difficulties giving effective hits, so they would run and take a few hits. This version also showed the highest amount of tries, with an average of 1.58 and an amplitude of 3.

Although this version did not show the best results regarding the performance metrics, it was a version with positive ratings and feedback about the music, so the cause for those low results could be because it was a more challenging level and not necessarily because of the music parameters. However, it did affect the perception and immersion of the game.

Table 4.5: Summary of performance variables in Version 3

V3	**Time**	**Accuracy**	**Health**	**Tries**
Average	152,93	41,41	45,83	1,58
Standard Deviation	79,40	39,40	31,47	1,00
Amplitude	222,60	100,00	90,00	3,00
Median	147,2	48,53	40	1

4.2.2.4 Version 4

The fourth version had a composition with a minor tone and a fast tempo. It followed the 'open world' map as versions 1 and 2. This version shared a few divergent opinions regarding the fit between the level and the music and how it helped in the immersion. The participants reported tension, anxiety, urgency, and a sense of danger ahead, probably because of the faster tempo. The anxiety feeling might have been inspired because of the minor tone, which is often characteristic of this composition. However, a few participants thought it was a little too fast.

The rating from the questionnaire showed positive feedback regarding the suitability of the music for the gameplay and the tone being aligned to the atmosphere, as the level design had a darker look, matching the minor tone of the music. Both of those aspects had an average rating of 4.

The matching of the tempo of the music with the pace of the gameplay received the lowest rating from all versions, with an average of 3.5, as the opinions were a bit divided as if the fast tempo provoked a feeling of battle and excitement to defeat the enemies or if it minimized the immersion. Therefore, given this division of opinions, the rating for how well the music contributes to the overall immersion in the game had an average of 3.8.

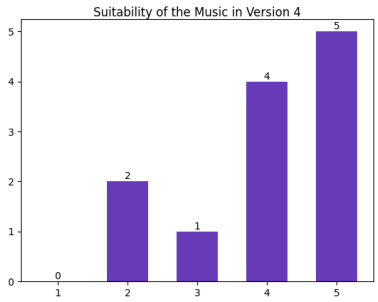

Figure 4.26: Suitability of the music in Version 4

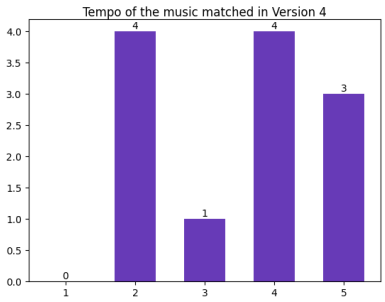

Figure 4.27: Tempo matched the gameplay pace in Version 4

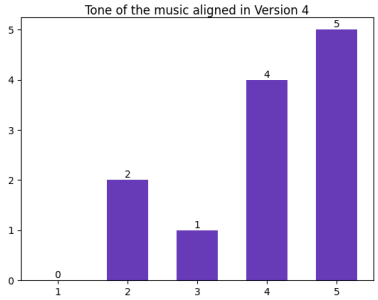

Figure 4.28: Tone of the music version aligns with the game in Version 4

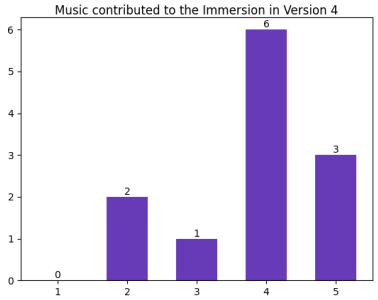

Figure 4.29: How music contributes to the immersion in Version 4

Regarding the performance variables, this version showed the lowest conclusion time, averaging 63.88 seconds. This value is similar to the one from version 1, and both used a composition with a fast tempo. Therefore, there might have a relation between music with a faster tempo provoking a feeling of rush in the player, so they would try to finish the game quicker.

In addition, the accuracy rate and final heath values were in the middle of the values from the other versions. Compared with version 1 (major tone and fast tempo), the accuracy rate was more than double in version 4, even though they had the same number of participants that did not interact with enemies. So it seemed that players tended to engage more in this version with a minor tone. However, as they interacted more with enemies, the final health was lower than version 1, with an average of 55.83.

For the number of tries, it was reported an average of 1.08. Of all twelve participants for this version, only one had to play twice to succeed.

Table 4.6: Summary of performance variables in Version 4

V4	**Time**	**Accuracy**	**Health**	**Tries**
Average	63,88	45,94	55,83	1,08
Standard Deviation	21,58	38,02	33,70	0,29
Amplitude	69,10	93,75	90,00	1,00
Median	62,3	57,82	40	1

4.2.2.5 Version 5

This version used a composition with a minor tone and medium tempo. Version 5 showed similar results to version 2 (major tone and medium tempo) in the questionnaire ratings and the performance variables. Regarding the participant's feedback, the opinions appear to be divided. Some were more engaged in conflicts with the enemies because they were excited and less tense. However, other participants claimed that a medium tempo created more suspense, urging a sense of slow caution and being less motivated to engage with enemies. A few players did mention that the slightly slower tempo compared to version 4 made them less emote to engage with enemies.

As mentioned, the ratings from the questionnaire were similar to the ones from version 2. For the suitability of the music for the gameplay, it had an average of 3.8. The fit between the tone and the tempo of the piece with the gameplay pace and atmosphere showed an average rating of 3.6 for both, demonstrating the division of opinion of the participants. However, even though the views about tempo and tone were divergent, the rating for how well the music contributed to the immersion showed a positive response, with an average of 4.

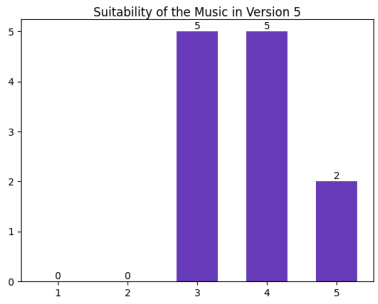

Figure 4.30: Suitability of the music in Version 5

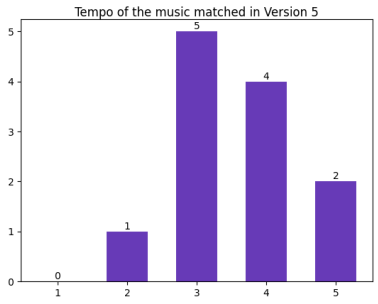

Figure 4.31: Tempo matched the gameplay pace in Version 5

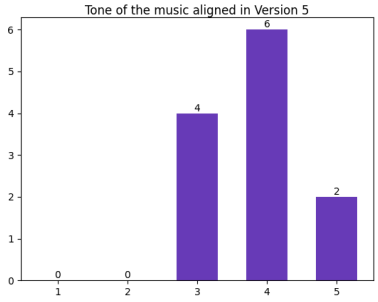

Figure 4.32: Tone of the music version aligns with the game in Version 5

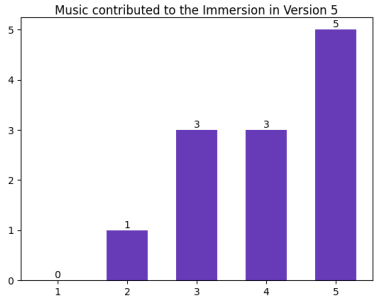

Figure 4.33: How music contributes to the immersion in Version 5

Considering the performance variables, the average values for this version were mainly in the middle of the ones from other versions for all variables. For the conclusion time, the average was of 104.83 seconds. This value was higher when compared with version 2. One possible reason for this slight difference is that players engage more with enemies in this version, as can be seen in the values from accuracy, where only one player never interacted with enemies. In contrast, in version 2, two players did not engage at all. The difference in accuracy is not that high, as this version showed an average of 55,58%. This could also be seen when analyzing the final health. This version had an average final health of 50, which demonstrates that players interacted more with enemies in this version. Lastly, only one of the participants had to play the level twice to succeed, while the rest did it in one try.

Table 4.7: Summary of performance variables in Version 5

V5	**Time**	**Accuracy**	**Health**	**Tries**
Average	104,83	55,58	50,00	1,08
Standard Deviation	50,45	29,83	19,07	0,29
Amplitude	180,50	100,00	70,00	1,00
Median	107,25	56,335	50	1

4.2.2.6 Version 6

This version was also a maze with a composition with a minor tone and a slow tempo. Similar to version 3, this version's ratings and feedback were also mostly positive. In general, version 6 had almost all the best ratings in the questionnaire, demonstrating that this music matched well with the maze.

In more detail, the participants claimed that the music invoked a sense of being lost in a dangerous place, which made it more challenging, and created more anticipation, tension, anxiety, and excitement. Although anxiety might seem negative, players reported that the thrills increased the immersion and helped set the atmosphere, making it seem like the stakes were higher. Overall, participants claimed that combining the minor tone with a slow tempo stirred a vibe of suspense that matched the labyrinth concept. Therefore they got more invested and wanted to engage more.

As mentioned, the ratings from the questionnaire showed high results. The song's suitability with the gameplay had an average rating of 4.1, the second-highest value for this question. The match between tempo and the gameplay pace also received a high average rating of 4, while the fit between tone and the game atmosphere had an average rating of 4.5. When comparing these ratings with the ones from version 3 (3.8 and 4), it is possible that the participants would rather have a minor tone with a slower tempo music than a major tone and a slower tempo. Lastly, regarding how well the music contributes to the immersion, this version showed the highest average rating of 4.5.

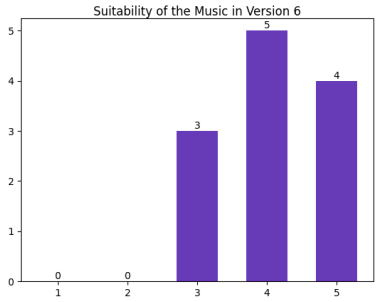

Figure 4.34: Suitability of the music in Version 6

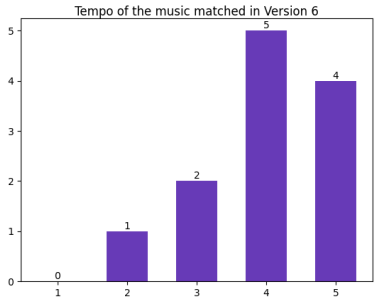

Figure 4.35: Tempo matched the gameplay pace in Version 6

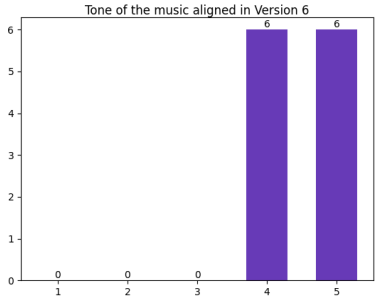

Figure 4.36: Tone of the music version aligns with the game in Version 6

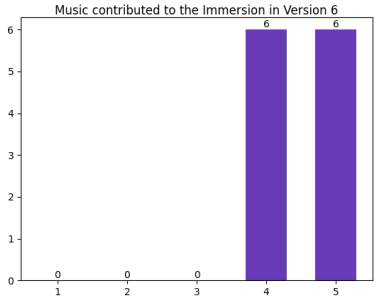

Figure 4.37: How music contributes to the immersion in Version 6

Regarding the performance variables, the average ratings were similar to the ones from version 3. The conclusion time for this version was also one of the highest, averaging 142.91 seconds. As mentioned before, it was expected that the version with the labyrinth (versions 3 and 6) would have a higher-conclusion time because of the extra challenge of finding the way out. The number of tries was also slightly higher than in other phases, with an average of 1.28, where only three players needed two attempts to conclude the level.

The rate of accuracy hits in this version was also higher than in version 3, averaging 51,81%. The players engaged more in this version, as can be seen in the number of players that did not interact with enemies. In version 6, only two participants did not engage in combat, whereas in version 3, five participants did not engage. This number confirms the feedback of the players that they felt more involved and immersed in this version than with version 3. This higher level of engagement in combat can also explain why the average final health of the player was lower than in all other versions, with a rate of 41,67.

Overall, this version showed one of the best rates and feedback out of all the versions. Where players felt more immersed, and the tone and tempo matched well with the atmosphere and pace of the gameplay. The table below gathers a summary of all performance variables for this version.

Table 4.8: Summary of performance variables in Version 6

V6	**Time**	**Accuracy**	**Health**	**Tries**
Average	142,91	51,81	41,67	1,25
Standard Deviation	71,66	51,81	24,43	0,45
Amplitude	258,80	92,59	80,00	1,00
Median	108	48,28	40	1

4.2.3 Conclusion Section

In this final section of the form, participants were asked which version they liked the most and the one they liked the least and why. The result is represented in the table below.

Table 4.9: Number of Favorite and Least Favorites for each version

Versions	Number of Favorites	Number of Least Favorite
Version 1	2	3
Version 2	3	7
Version 3	8	3
Version 4	1	4
Version 5	4	5
Version 6	6	2

The table shows that versions 3 and 6 were marked as the favorites, whereas versions 2 and 5 were the least favorite. It is interesting to notice that the least favorite ones are both with a medium tempo. Most of the explanation about why versions 3 and 6 were the favorite revolved around being the ones where the music instigated more emotions, making them more engaged. Furthermore, the suspense and thrill evoked by the combination of the game and music helped set the atmosphere, making the game more enjoyable. For the participants that chose the labyrinth versions, their least favorite was usually because they found it challenging and not necessarily because of the music.

The participants that chose versions 2 and 5 as their least favorite had similar reasons. It was mainly because the level was too simple, or they felt like the music was too slow for the pace of the gameplay, which made it less exciting and immersive. As opposed to the labyrinth, the players chose both these versions as their favorites because they thought it was easier and they had more freedom. However, a few participants said they were the most engaging or the tempo matched the gameplay best.

Next, a few questions were in a Likert scale format ranging from 1 (Not at All) to 5 (Extremely). The questions are described below.

- Did you find the variation in tempo between the versions noticeable and meaningful?
- Did you find the variation in tonality between the versions noticeable and meaningful?
- Do you think the music in the game helped or hindered your overall performance? How?
- Did the music influence your emotions or engagement level while playing the game? How?

Regarding the noticeable tempo variation, an average rating of 3.6 and a median of 4 is displayed for the first question. According to some participants, they could notice a difference but sometimes had trouble establishing whether each one had a medium tempo or a slower tempo, for example. So although they had difficulty identifying which tempo was sometimes, they could recognize a difference, and it showed some impact, as mentioned in the previous section when analyzing each version's results. However, most participants could correctly identify the differences between the tempo. The chart below represents the answers to this question.

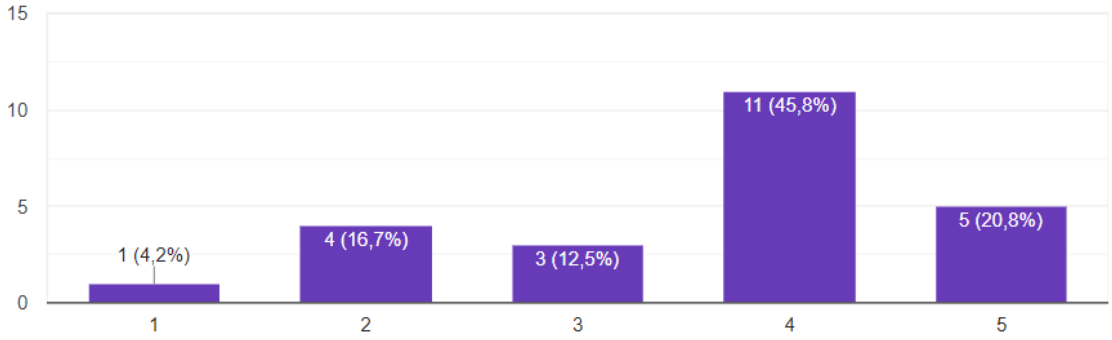

Figure 4.38: How noticeable is the tempo variation between versions?

The second question is about how noticeable the different tonalities are between versions. Compared to the tempo, noticing the difference between the two tonalities was harder for the participants. The average rating for this question was 3.2 and a median of 3, showing that it took more work to identify this difference between tones than the tempo. However, a point that should be taken is that some participants did not play versions with different tonalities, as was the case for those who played Alternatives A (Versions 1, 2, and 3) and Alternative D (Versions 4, 5, and 6). Although noticing the difference was a bit harder for players, some quickly identified it correctly and could make meaningful observations about it.

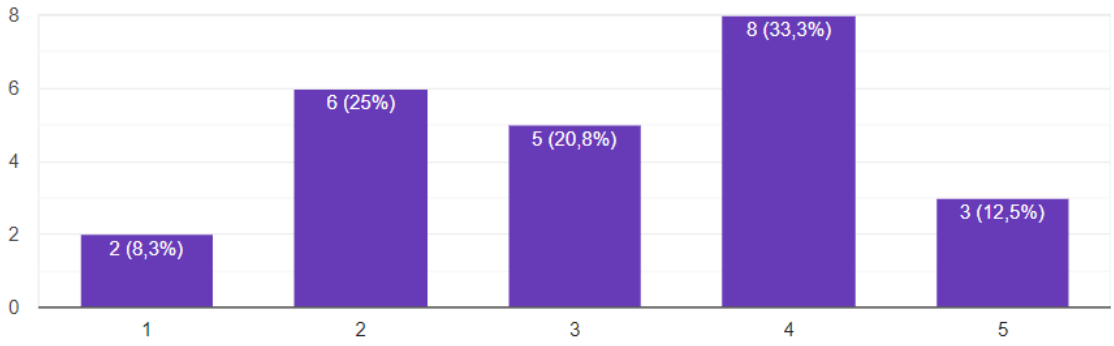

Figure 4.39: How noticeable is the tonality variation between versions?

The third question aimed to determine if music had any positive or negative impact on the player's performance, whether it helped or hindered the gameplay, and if so, how? Analyzing the answers in the chart below resulted in an average rating of 4.2 and a median of 4, implying that the music impacted the gameplay for the participants.

According to the feedback in the open field of the form, the music could impact in different ways. For example, in some versions, the music was engaging enough to interact with more enemies, indicated the pace, and improved the feeling; overall, it helped because it made it more immersive, and thus, they played more focused. Furthermore, it also helped to set the atmosphere of the game, and the tempo of the music influenced how fast they would finish the level. However,

it also could impact negatively, as players reported being tense and anxious, affecting their playing in a harmful manner.

Overall, the participant's feedback mainly reported that music impacted their performance positively.

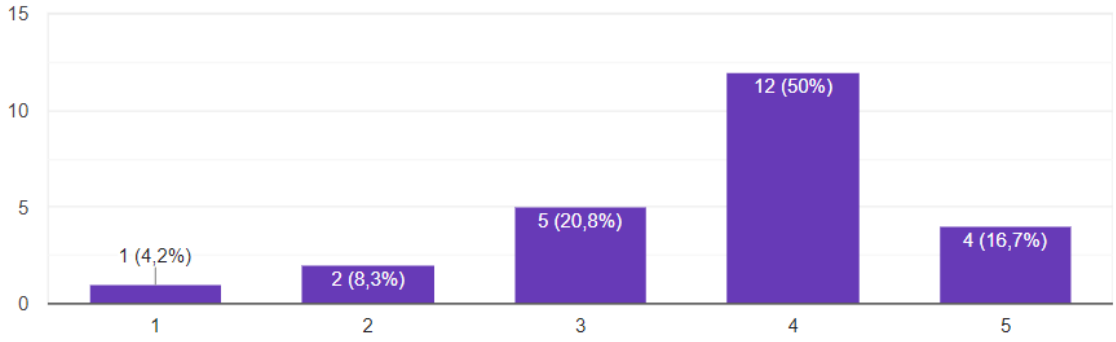

Figure 4.40: Did the music help or hinder the performance?

The last question aimed to determine if the music influenced the player's emotions or engagement level while playing the game, and similar to the previous question, it showed a positive result. The average rating for this question was 4.3, with a median of 4.

With the participant's feedback on how it influenced their emotions or engagement, it was reported that they enjoyed the game more because of the music. In addition, the music helped to set the vibe of the game, evoking and intensifying their emotions. For example, in the labyrinth, the music helped make the player feel more lost. The music also contributed to stirring tension in the player, making them feel more focused, and without it, the game would lose a significant portion of the emotion. Depending on the music version, the players also reported being more scared or relaxed.

Overall, participants agreed that the music influenced their emotions and engagement in the game, even if in different forms.

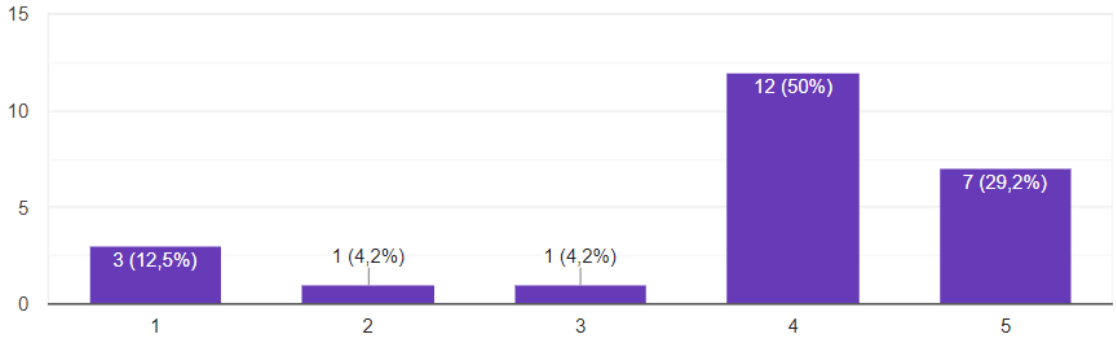

Figure 4.41: Did the music influence emotions or engagement level while playing?

4.3 Physiological Measurements

This section will report the results and the analysis of the physiologic responses gathered from the participants during the gameplay. As mentioned, the physiological measurements used were muscle activity (EMG), Heartbeats (ECG), and skin conductance (EDA). The device used to measure those responses was the BITalino.

The EMG sensor is used to measure muscle activity, translating electrical signals into numerical values that are triggered by muscle activation. The default unit of measurement for this sensor is millivolts (mV).

The ECG sensor enables the translation of electrical signals from heartbeats into numerical values. This sensor's default unit of measurement is also millivolts (mV).

Lastly, the EDA sensor can accurately measure the electrical properties of the skin, which often changes, caused by alterations in sweat secretion, when people are aroused or relaxed. So when there is sweat production, the resistance of our skin changes, and the EDA is responsible for translating these resistance changes. This sensor's default unit of measurement is micro siemens (µS), which is the unit of electric conductance in the International System of Units (SI).

The following subsections will report the results obtained during the tests for each physiological measurement and how they were analyzed.

4.3.1 Electromyography (EMG) Results

For the measurements of the muscle activity, 19 results were collected, as the other five results were not recorded properly because of some device failures. This measurement was analyzed considering how muscle activity appeared in the signal. An example of some action is displayed in figure 4.42.

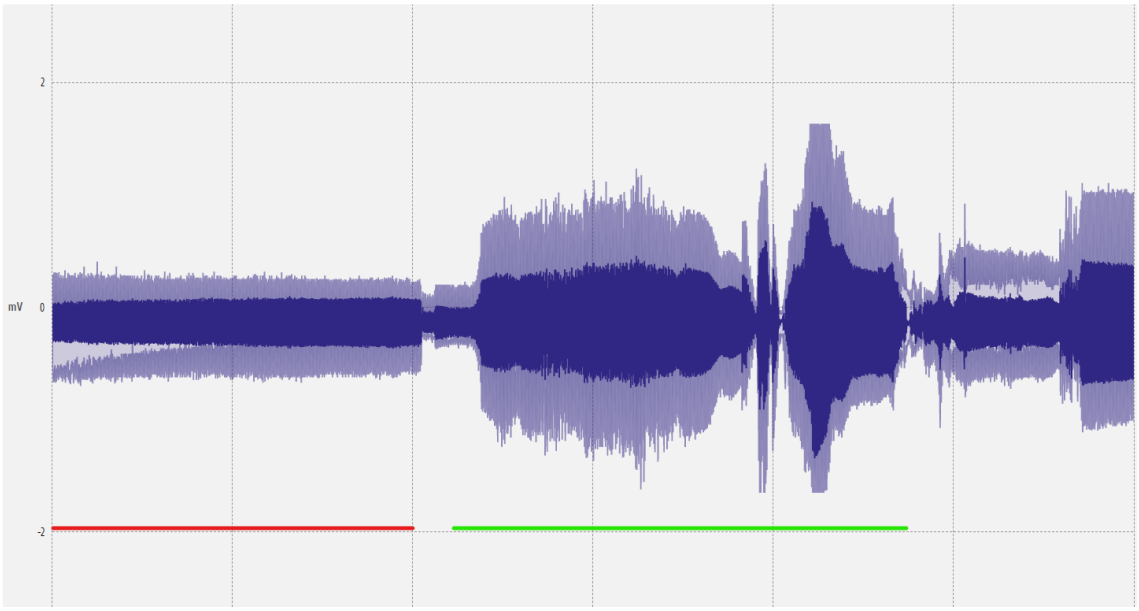

Figure 4.42: EMG signal example

The part signed with red shows regular activity, with the muscle not displaying much action. The green part indicates a contraction of the forearm muscle, which could be interpreted by clicking the mouse button, thus, an act from the player. Therefore, the spikes represented more decisive actions, while the rest showed little activity and, depending on the amplitude, could mean more tension from the player.

Most of the time, the feedback acquired from the questionnaire about each version matched the results from the physiological measurements. For example, when the player reported feeling tension, the regular activity of the muscle had a higher constant amplitude. However, the results for a version showed many variations, as some participants showed more tension, and others showed less tension and more contractions.

For version 1, the results were varied, but overall, there was some slight constant tension but more high spikes of contraction, displaying more player interaction with enemies. When players reported feeling tension and pressure, it did show in the recording with constant higher regular activity. Furthermore, when reporting excitement, the frequency of high spikes of contractions was increased.

On the other hand, version 2 did not show much tension, less than version 1, as players seemed more relaxed throughout the gameplay, but they did display some higher contractions. This version showed the highest amplitude for the contractions, which could be explained by being more relaxed overall and only tensing when engaging with enemies.

In version 3, most participants showed high tension throughout all levels, even when many players did not engage with enemies. The contraction spikes did not show much amplitude, probably because the muscles were tense even when not attacking.

Version 4 was similar to version 2. Not much constant tension, but it showed higher contraction spikes with longer amplitude. This version had divided opinions and divergent results. When players said that the faster music from this version instigated the feeling of battle, they showed higher constant activity and spikes. However, some said that the music did not evoke the battle feeling, and therefore they did not engage much, which showed in the recording.

Version 5 was the one that showed a minor activity overall. As some participants mentioned, it appeared to be a more relaxed level, and it show in the measurements, not having much constant tension nor many high spikes of contractions.

Lastly, version 6 had a higher constant tension and higher activity overall. Many participants reported feeling much pressure and tension, which could be seen in the recordings, with the regular activity having a higher amplitude than other versions and showing many constant high spikes of contractions.

4.3.2 Electrocardiogram (ECG) Results

The same issue happened when measuring the cardiac activity as the EMG and only 19 tests were successfully recorded, making each version have a different amount of recordings. An electrocardiogram shows many different kinds of information, such as the strength and timing of the

electrical signals passing through each part of the heart and how fast your heart is beating. However, for this thesis purpose, only the frequency was analyzed, that is, the bpm (beats per minute) for each version played. An example of the recording of a version is shown in figure 4.43.

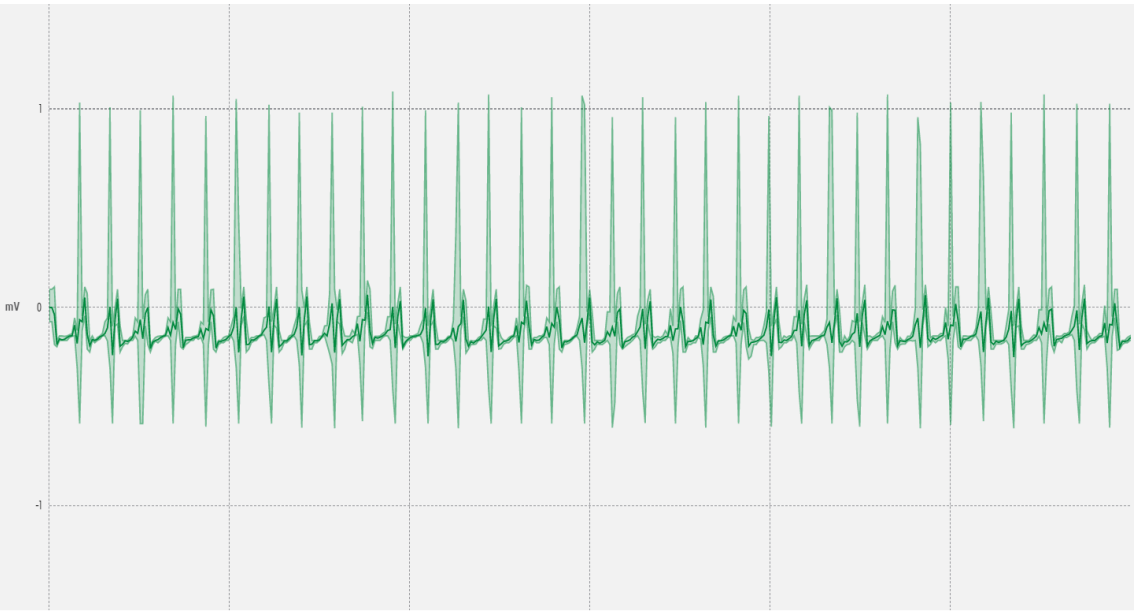

Figure 4.43: ECG signal example

Each of the spikes represents a heartbeat. Therefore, the BPM for each version was calculated by counting how many beats there were for the duration of the gameplay. Such as the formula 4.1:

$$\text{BPM} = \frac{\text{Beats} \times 60}{\text{duration of gameplay}} \tag{4.1}$$

The average BPM considering all versions, was 82.5 BPM. Furthermore, the average BPM for each version is displayed in the table 4.10.

Table 4.10: Average BPM for each version

Tempo \ Tone	**Major**	**Minor**
Fast	83,4	83,8
Medium	81,5	78,6
Slow	83,1	84,7

By analyzing the table, it is possible to see that even though it was the slower music, version 6 (Slow-Min) had the highest average BPM. After version 6, versions 1 (Fast-Maj) and 4 (Fast-Min) followed with similar averages, the ones with the fastest tempo. Version 3 (Slow-Maj), which also had a slower tempo, showed a higher average BPM than versions 2 and 5, with a medium tempo.

Table 4.11: Median of BPM for each version

Tempo \ Tone	Major	Minor
Fast	84	88,5
Medium	87	81
Slow	86	86

As many participants mentioned, version 6 stirred the most tension and anxiety. It was one of the most fitting music, increasing the immersion and contributing to a higher BPM, even though it had the slowest tempo. As mentioned, Version 1 and 4 had very similar average BPM, 83.4 and 83.8, and both consisted of a faster tempo that might have instigated excitement and a battle feeling, which could have increased the heart rate.

Furthermore, although versions 2 and 5 had medium tempo, the average BPM was the slowest. This could have happened because, as some players mentioned, those versions felt more relaxed and calm. Both versions had different tonalities, and the one with a minor tone (version 5) caused less impact on the heart rate.

However, version 3 had the same tempo as version 6 but showed a slower average BPM, which could indicate a difference in feeling caused by opposed tonalities, where the minor tone (version 6) had more impact.

In conclusion, there was a comparable tempo difference within all versions and a slight difference when looking at the tonality, mainly with the slow and medium tempos versions.

4.3.3 Electrodermal activity (EDA) Results

In the middle of the tests, the sensor for the EDA started displaying issues with contact with the device. Therefore, only 14 tests were successfully recorded.

Analyzing electrodermal activity (or galvanic skin response (GSR)) could be complex, as it is a measurement that can differ significantly between individuals due to factors such as skin characteristics and sweat gland activity. Therefore, within the scope of this work, the data was analyzed by using the average variations of each version than the actual minimum and maximum values. An example of the EDA measurement is presented in figure 4.44.

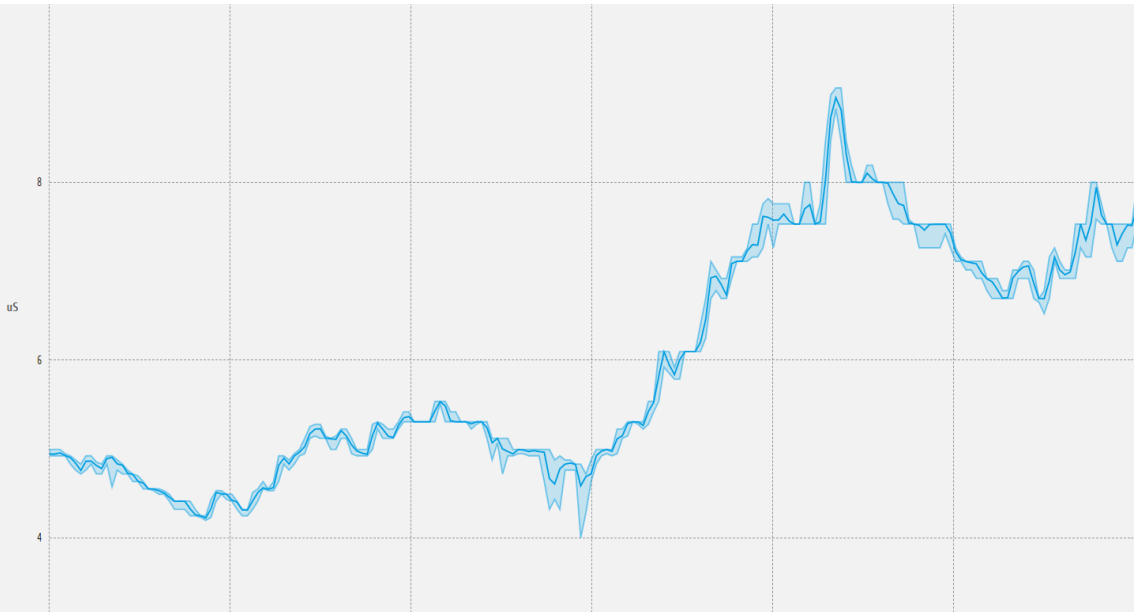

Figure 4.44: EDA signal example

To analyze the results of electrodermal activity, the minimum and maximum values from each version for each player were annotated. The average amplitude Variation for each version is going to be used to support the analysis, which is shown in the table 4.12.

Table 4.12: Average amplitude of EDA for each version

Tempo \ Tone	**Major**	**Minor**
Fast	4	5,1
Medium	2.3	1.1
Slow	4.5	9.5

Analyzing the values from the table 4.12, it is possible to observe that version 6 (Slow-Min) had the highest average variation, of 9.5 of skin conductivity, which indicates higher variation levels of sweat, just as it was the version with the highest average BPM. Version 4 (Fast-Min) is the second highest average variation, of 5.1 µS, followed by versions 3 (Slow-Maj) and 1 (Fast-Maj), which is also a similar ranking to the one from the ECG. Again, in versions 2 and 5, with medium tempo, we can observe, again, similar results regarding the slightest variation as seen in the previous section.

There were also analyzed the individual values for each version, which were the largest and smallest variations. Again, version 6 showed the biggest variation of 24 µS. Following, version 4, with a variation of 18 µS. Version 2 was next, with an average individual variation of 10.4µS. And lastly, versions 1, 3, and 5, with the same variation of 10 µS.

In conclusion, we can deduce that the results of EDA in terms of the average variation seem similar to the ECG results. The version with the highest heart rate was also the one with the biggest

variation in electrodermal activity, which might imply a relationship between a higher heart rate and higher sweat levels.

Chapter 5

Discussion

This chapter interprets the results obtained in this study from the questionnaire and the physiological responses. It aims to critically examine the effects in light of the research questions and existing literature. It explores the relationships between music characteristics and physiological measurements and tries to identify patterns. Lastly, the limitations of the study are presented.

5.1 Interpretation of Results

Initially, when analyzing the results for version 1 (Fast-Maj) from the questionnaire and the physiologic measurements, it was possible to connect the low completion time and low engagement with the rush provoked by the faster tempo and the slightly higher regular activity. When players mentioned feeling tension, it showed in the results from the EMG with constant muscle tension and having a higher BPM in the ECG than the average, as well as an EDA higher variation. Furthermore, when participants described feeling excitement, the EMG showed more spikes and, therefore, more interaction in the game. In conclusion, the fast tempo in this version could impact in two different ways. Either stirring rush and, thus, lower engagement and higher constant tension. Or by provoking excitement, increasing player engagement, and displaying more spikes in the EMG. However, excitement was not mentioned as frequently as the sensation of rush. When comparing the ECG, the tonality did not cause much difference, as the values from versions 1 and 4 were similar.

On the other hand, for version 2 (Med-Maj), the medium tempo provoked a more cautious and relaxed vibe when compared with the tension in version 1. This calmer atmosphere also was shown in the result from the EMG, ECG, and EDA, as the EMG did not record much constant muscle tension, the ECG had one of the slowest BPM averages, and the EDA displayed minor variation. The EMG results showed more amplitude contrast when engaging with enemies with high spikes. Therefore, the medium tempo and major tonality created a calmer and more relaxed vibe, only changing to slight tension when the player engaged in combat.

When analyzing version 3 (Slow-Maj), the slower tempo stirred a higher tension among the two previous versions. Although the EMG spikes did not show high amplitude, the regular muscle

activity had a constant higher amplitude, indicating that the participant was already in high tension. In addition, players in this version avoided confrontation, which appeared in the EMG recording, not having many spikes. Comparing the ECG results, this version showed a slower average than versions 1, 4 (both fast tempo), and 6 (Slow-Min), although it was still higher than the average BPM. When looking at version 6, the difference in the ECG could represent a different impact caused by tonality, as version 6, with the same tempo, had a higher BPM and a characteristic of avoiding confrontation. The EDA ratings were similar to the ECG.

Starting to interpret the results from the versions with minor tonality, version 4 (Fast-Min) showed similar results to version 1 regarding the rush provoked, indicating a possible relation with the rush and faster tempo, as both versions were quicker to be completed. However, players in this version seemed to engage more in combat, as shown in the EMG results, as it had many contraction spikes throughout the level with high amplitude, indicating higher tension when engaging. Thus, this increased engagement, compared to version 1, might result from the minor tone. This version also had the second-highest average BPM and EDA variation, showing the feeling of rush and tension when engaging.

Similar to the feeling stirred by version 2, version 5 (Med-Min) also appeared to create a calmer and more relaxed atmosphere, as mentioned in the participants and the results from the physiological measurements. This version's EMG did not show constant muscle tension nor high or regular contractions. It also had the slowest BPM, way less than the average BPM, and also the slightest variation in EDA, corroborating with the feedback from players that version 5 was more relaxed. However, players showed more engagement in this version than in version 2, which could result from the minor tone, as happened when comparing versions 1 and 4.

Lastly, version 6 (Slow-Min) participants displayed high tension and great immersion and engagement, resulting in a higher accuracy of hits than version 3. Those characteristics might result from the slow tempo and minor tone. The more robust engagement can be analyzed from the EMG as it showed constant high muscle tension and contraction. In addition, the ECG and EDA displayed the highest average BPM and the higher skin conductivity variation, respectively.

After interpreting all the results from each version, it became possible to answer the research questions.

RQ1: Can one measure the impact of specific music characteristics variations on a player's game experience and performance, and if so, how?

It is possible to see how the different music characteristics variations, namely tempo and tonality, impacted the experience and performance of the player. Music with a faster tempo evoked the feeling of rush and tension in the player, which consequently diminished the engagement, and as shown in the results, those versions were the ones with the shortest completion time. However, the engagement increased when combining the faster tempo with the minor tone. As a result, the accuracy of hits was higher with this version, and the average final health of the player decreased.

Next, looking at the versions with medium tempo provoked a more cautious and relaxed vibe

compared to the tension and rush of the faster tempo. This calmer atmosphere contributed to a higher completion time than versions 1 and 4 and the highest accuracy of hits, as the player felt less nervous and more cautious. Furthermore, when comparing the tonalities of versions 2 and 5, the version with the minor tone displayed a higher player engagement and, therefore, a higher completion time and a minor average final health. However, the major tone seemed to make the player a bit more cautious when interacting, resulting in higher accuracy of hits than in the minor version.

Lastly, both versions with a slow tempo instigated the highest tension in players among all versions. However, the version with a minor tone did demonstrate stronger engagement and immersion. For these two levels, a shorter conclusion time would imply a higher engagement once completing the labyrinth faster showed more attention from the player, which is the case of the version with a minor key. Furthermore, this version also showed a higher accuracy rate, displaying a higher focus, and the increased interaction in combat ended up causing a lower average health. According to some participants, even though they expected faster-paced music given the gameplay characteristics, they thought that the slower tempo and minor tone made them more engaged in exploring and playing more carefully, as it created an atmosphere of high stakes.

RQ2: Can physiological measurements be used as part of that assessment, and how?

After analyzing the physiological response recordings, it is possible to infer that they can be used to support the impact of music characteristics variations on a player's game experience and performance. However, it is essential to consider individual differences and contextual factors that might influence physiological responses.

In the case of EMG recordings, the activity in the forearm muscle provided valuable information about the players' tension levels and engagement. Higher muscle activity was detected during confrontation situations, for example. However, when feeling calmer and more relaxed, muscle activity decreases.

In addition, the ECG demonstrates an alteration in the heart rate. For example, when accompanied by high-tempo music, participants exhibited increased heart rates, reflecting heightened excitement and engagement. Contrarily, a decreased heart rate was observed with medium-tempo music, suggesting a relaxation response.

Furthermore, the EDA measurements offered insights into the players' emotional arousal and stress levels. Increased sweat gland activity, as indicated by higher skin conductance levels, was observed during challenging moments or when players displayed high tension. On the other hand, when feeling calmer, the skin conductance levels showed lower variations.

Overall, it was possible to notice a relationship among the three physiological measurements: EMG, ECG, and EDA. For example, during intense and high-tension and confrontation moments in the gameplay, characterized by high muscle tension captured by the EMG, the ECG detects a corresponding increase in heart rate, and a more significant variation in the skin conductance levels can be observed. Mainly, it was possible to see a strong correlation between ECG and EDA

results in almost all versions, where higher heart rates were often accompanied by higher variation in the EDA.

5.2 Limitations of the Study

Although this research might have shown results for the data acquired, it is essential to acknowledge certain limitations that may have influenced the findings and should be considered when interpreting the results.

Firstly, the sample size of participants in this study was relatively small, which may limit the generalization of the findings to a larger population. Future research with a more extensive and diverse participant pool would enhance the external validity of the results.

Secondly, the study focused on a specific genre of video games and explored the impact of music variations within that genre. The findings may not necessarily extend to other game genres or contexts.

Furthermore, the physiological measurements were collected using a BITalino device, which has some constraints regarding accuracy and precision. So, it is important to consider the potential limitations associated with the device's hardware and signal processing algorithms. Additionally, the OpenSignals software used for data acquisition and analysis has limitations. It could not process data for more than one minute of the recordings, usually around 10 minutes, so the analysis had to be done manually.

Lastly, this study focused on only three physiological measurements, EMG, ECG, and EDA. The analysis did not include other physiological indicators, such as respiratory rate or blood pressure, that could generate relevant results and analysis. Therefore, the findings of this study should be interpreted within the context of these specific measurements and may only capture some of the physiological responses to music in games.

Chapter 6

Conclusion and Future Work

This work aimed to discover if measuring how different music characteristics variations can impact a player's performance. Furthermore, it also tried to figure out if physiological measurements be used as part of that assessment and, consequently, how.

Before starting the implementation and development, the state-of-the-art was thoroughly reviewed and examined, considering topics such as the video game industry, music and sound effects in video games, physiological responses, and the influence of music in other fields, like cinema and medicine. This literature review provided a deeper understanding of the area that would serve as support for the development process.

To answer those questions, six music compositions were produced using the same pattern, variating on two characteristics: tempo and tonality. The tempo could have three possibilities: a fast BPM, a medium, and a slow one. The tonality differs in major and minor tones, respectively, in C major and C minor. Those six compositions were placed each in similar game levels developed.

The development started after analyzing the design requirements and establishing the game concept. It was decided that the game would have a 3D dimensionality, leveraging the variety of online assets and aiming to create a more immersive atmosphere. Drawing inspiration from the assets chosen, a medieval aesthetic was selected as the game's theme.

The test phase began after developing the game and creating the music compositions. During tests, the participants answered a questionnaire with personal questions, such as their gaming experience and music perception. Furthermore, they were also asked questions about each game version they played. While playing, they were connected to a few sensors to record and measure the physiological responses, namely EMG, ECG, and EDA. A few performance variables were also measured for each version, for example, the completion time, accuracy of hit, and final health.

After completing the tests, the data acquired were analyzed, and the results were taken, considering the questionnaire and physiological measurements individually. Later, both results were analyzed to develop a relationship between music parameters, player performance, and physiological measurements. Thus, possibly answering the research questions.

Overall, it was possible to answer the questions proposed with the results obtained fully. The findings of this study indicate a significant association between music characteristics and player

performance. Furthermore, integrating physiological measurements provided additional depth to our understanding of the player experience.

Several possibilities for future research can further enhance the understanding of the relationship between physiological measurements, music, and gaming experiences. Firstly, considering the limitations associated with the BITalino device and the OpenSignals software, future studies should explore alternative physiological sensors and data acquisition platforms to improve the accuracy and reliability of the recorded measurements.

Additionally, increasing the sample size of participants could enhance the generalizability of the findings. Although this study had a reasonable sample size, increasing the number of participants with diverse backgrounds and gaming experience levels would provide a more robust and representative dataset.

Furthermore, as mentioned in the study's limitations, the current research focused on a specific genre, but investigating other game genres could promote a more comprehensive understanding of how music influences different gaming contexts, as different game genres can evoke distinct emotional and cognitive responses.

Lastly, integrating additional physiological measurements beyond the ones examined in this study, such as eye tracking, electroencephalography (EEG), respiratory rate, and blood pressure, would deliver a vaster approach to studying the impact of music on gameplay performance.

In conclusion, this research contributes to the knowledge of the role of music in video games. It highlights the importance of considering music characteristics and their impact on player experiences and performance. This study also sheds light on the physiological responses associated with music characteristics variations by incorporating physiological measurements.

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