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Not just Atmosphere: Game Music Design for Accessible In-Game Information Communication

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ABSTRACT

Visual impairment can make gamers more reliant on auditory feedback. Sound effects have been known to have a significant impact on improving gaming experiences for people with visual impairments. Little has been known, however, on the impact music itself could have. How can game music improve game accessibility to Visually Impaired and Blind (VIB)? We employed a design science process where we started with interviews with 6 VIB and 6 sighted participants to develop an initial answer to the question. Based on that we composed and evaluated 3 pieces of game music for the game *Returnal* by Housemarque. We evaluated the test compositions with the participants along with original *Returnal* music. Our findings indicated that music generally did not play a significant accessibility role for VIB, however, the test composition designed to provide heightened environmental information and player status feedback was highly appreciated by the participants. We, hence, contribute an approach to game music composition that is likely to increase game accessibility to VIB and sighted.

CCS CONCEPTS

• **Social and professional topics** → **People with disabilities**;
• **Human-centered computing** → **Empirical studies in HCI**;
HCI theory, concepts and models.

KEYWORDS

game music, game accessibility, inclusion, blind gamers, visual impairment, composition, ludomusicology

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1 INTRODUCTION

Games are highly visual artifacts. However, they employ music and sound cues in communicating game information to players [31]. When gamers have a visual impairment, a dominant approach to

make games more accessible to them is to rely more heavily on audio in the forms of music and sound effects. While an estimate of the number of gamers with visual impairment is lacking, according to statistics of the World Health Organization [34], there are globally at least 2.2 billion people living with vision impairment who would significantly benefit from accessible games and inclusion in gaming culture.

While communicating visual cues as audio may be challenging, we have recently seen several games attain that goal. The *Last of Us Part II* is one such recent example, while the *Mortal Combat* series has been known for its playability even by fully blind people for years. These games, however, are the exception, and game accessibility to the blind and visually impaired remains a significant challenge [15]. Research has been exploring the impact of sound effects on game accessibility for users with and without vision impairment [12]. However, such research remains scarce and has predominantly focused on the atmosphere and psychological impact of game sound, more than how it can facilitate accessibility [14]. Furthermore, game sounds (and effects) are approached as the heroes of game accessibility, while game music is primarily seen as a tool to create atmosphere and immersion. Hence, the role of music in game accessibility remains under research. Philosophically, it is debatable how – if at all – music is different from sound effects. We do not aim to enter this debate, however, noteworthy is that in this research, sound effects are sounds that do not necessarily rhythmically sync with the music and are designed for a different purpose than music, but are there to indicate something to the player and with the intention of. Additionally, compositional tonal layers that make up music are intentionally composed by a composer in connection with or separate from gameplay, whereas sound effects reflect game play and are designed almost always in connection with it. Compositional tonal layers following each other by creating melodies, made with the intention of being musical, without serving any other purpose, were considered music by this definition, differentiating them from sound effects.

The question we would like to explore is: How can we compose game music that provides in-game information to facilitate game accessibility? To answer this question, we wanted to discern first how Visually Impaired and Blind (VIB) and sighted participants viewed the role of music in games. We conducted interviews with six VIB and six sighted participants. Based on findings from those interviews, we followed a design science process and composed three pieces of game music to evaluate which could be better able to communicate in-game information to the players and facilitate game accessibility. The tested compositions were for the game *Returnal* by Housemarque. Our findings indicate that when game music is



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designed to be informative, it can also contribute to improved game accessibility to VIB and enjoyability to sighted participants.

2 BACKGROUND

2.1 Game Accessibility

Game accessibility is understood as effort, designs, products, and technological features that aim to make games playable by everyone, primarily people with disabilities [1]. Many people with disabilities experience immense difficulties in accessing game technologies, and up to 90% of surveyed gamers with disabilities in one study reported access barriers to games because of disability [2]. Games can be inaccessible given that these technologies are highly visual, require fine motor abilities, and often employ auditory cues to communicate important information [5, 10]. Each of these aspects of gaming provides a challenge to a different disability group and hence, accessibility work is often needed to facilitate equal access to technology and opportunity.

Internationally, several governmental, commercial, and non-governmental organizations have released accessibility standards and guidelines, from relatively generic ones such as those for all web technologies by the World Wide Web Consortium (W3C), to specialized game-specific guidelines such as those published by AbleGamers or the website gameaccessibilityguidelines.com. Commercially, Microsoft, for example, recently released Xbox accessibility guidelines and established a dedicated accessibility testing panel [9]. A few notable game developers have released games with enhanced accessibility, such as Naughty Dog releasing *Last of Us 2* [29] and Santa Monica Studios releasing *God of War Ragnarök* [30], which won the Innovation in Accessibility award of the 2022 Game Awards [27]. These two games have been landmarks for VIB, as there are several anecdotal reports of the games being played by fully blind people. In the realm of research, researchers have investigated different game settings and how they can facilitate access for VIB. This has included high contrast features, sound effects, audio indicators [5], co-piloting, and other ways of social accessibility [3].

Given the nature of visual disabilities, audio has been of primary concern to facilitate game accessibility for VIB. Music and sound effects are thought to perform different functions in games; music tends to be used to communicate an atmosphere and feel, whereas sound effects tend to be the dominant way that games provide audio communication of in-game action and conditions (hitting an enemy or picking up an item as examples in most games). Given this assumed difference in function, it is important to understand the influence of both sound effects and music on gamers with visual impairments. In the ludomusicological (video game music research) literature [7, 11, 32], game music researchers have been careful not to draw sharp dividing lines between music and sound effects in terms of gameplay experience, emphasizing the need to extend the investigation to both sides of the border. Nonetheless, we see disparity in research attention. While the impact of sound effects has long been studied with VIB and sighted participants [6], game music has received comparatively less attention.

In terms of games themselves, while music is often employed to create a certain atmosphere or provoke emotions, there are some subgenres where game music provides more than that to the gamers.

For example, based on our anecdotal experience, rhythm and audio puzzle games require the player to be auditorily attuned to musical changes to play the game. Sound effects can play a relatively less important role in those games. However, these games are only one genre of games; they don't center on exploring a massive game environment, and they are designed to be mainly used by VIB and appeal relatively less to mainstream users. This can isolate VIB from playing other genres of games or mainstream games [2]. The participants of our study, as will be discussed in the following section, corroborated this anecdotal evidence, emphasizing that they also would like to play mainstream games more than games tailored for blind gamers. This is especially the case for low-vision gamers who can interact with the visual aspect of gaming to a certain extent and would like it to be there rather than play pure audio games. Overall, this highlights the need for exploring more ways to facilitate game accessibility, potentially through game music, as is our goal from this study.

2.2 Vision Impairment

The quality of vision is determined by various functions such as visual acuity, visual field, binocular vision, depth perception, color vision, sensitivity to light, and contrast perception [4]. Vision impairment, also known as visual impairment, is defined as presenting with visual acuity that falls below 6/12 in one's dominant eye [34]. It refers to a range of conditions affecting a person's ability to see, ranging from complete blindness to partial vision, and includes other visual conditions that affect the eyes or the brain. Multiple different reasons can cause vision impairments, such as genetic diseases, accidents that cause injuries, or age-related changes. Hence, one can be born with a visual impairment or acquire it for different reasons. Visual impairment does not mean 100% blindness in most cases [17].

Within vision impairment, low vision is characterized by a visual acuity that falls within the range of 6/60 to 6/18 or a visual field that is less than or equal to 20 degrees, even after applying the best possible correction to the better eye [4]. In contrast, blindness refers to a complete absence of vision, where individuals with a visual acuity of less than 20/200 or a visual field less than 20° in the better eye, despite the best possible correction, are considered fully blind [17]. Overall, this means that visual impairment occurs on a large spectrum, and some types of it can involve seeing the general shapes, forms, and some colors of objects (low vision), while others are closer to full blindness. Hence, there is a need for different accommodations, depending on the level of the impairment.

Most research that we see on visual impairments and game accessibility, however, tends to treat visual impairments as a lump category [15, 16]. Game accessibility solutions need to accommodate different needs, as mentioned, within the wide spectrum of vision impairments. The aim of this research is to explore one such approach to inclusion for people with low vision and blindness, allowing for increased access and immersion while simultaneously providing visual and auditory output to each user group through game music.

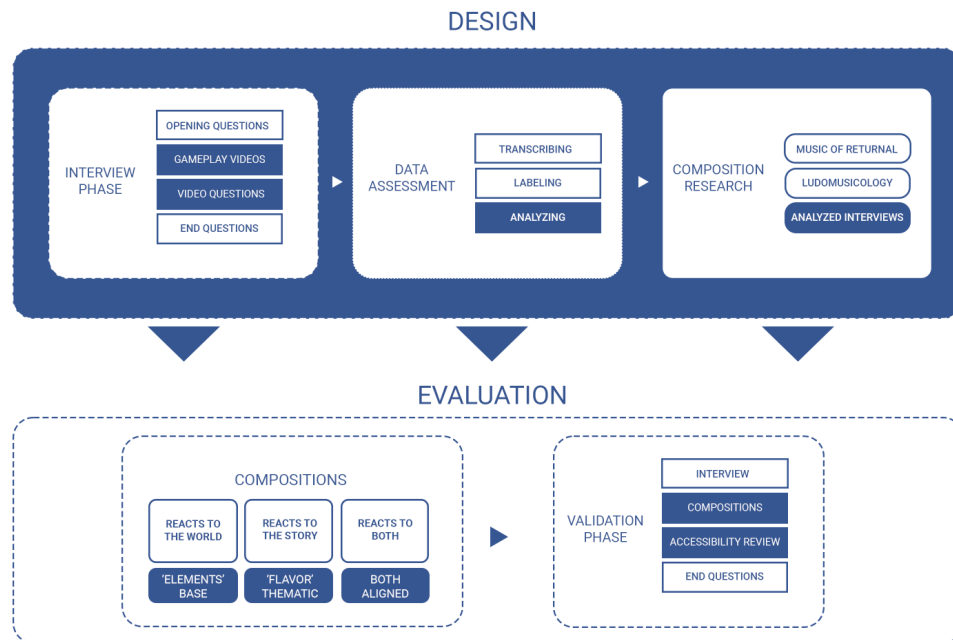


Figure 1: The Design Science Research approach employed in this study.

3 METHODS AND FINDINGS

3.1 Research Approach

To address the research question, we utilized a Design Science Research (DSR) approach that allowed us to develop and evaluate an approach to composing game music for game accessibility. DSR allows for the systematic and controlled design, development, and evaluation of theoretical and practical artifacts [19, 25]. DSR is most traditionally composed of two research phases: design and evaluation. In the context of this research, we initially started **the first design phase** with interviews with VIB and sighted participants to understand their perception of game music. Gameplay footage was used in the interviews as a catalyst for discussion. Based on these interviews, the main author composed several pieces of game music to evaluate which would be better able to make a game more accessible. The game in this case was *Returnal*, by Housemarque, which was selected as the lead author had easy access to the game developers and the material needed for this research. **The second process of DSR**, evaluation, was conducted through interviews with VIB and sighted participants to see how they perceived the different composition designs proposed and to learn which approach to game music composition could be better at facilitating game accessibility. In the following sections, we describe the design and evaluation process more in depth. Figure 1 provides a summary of the DSR approach.

3.2 Participants

The research aimed to work with VIB and sighted participants to compare their perceptions of game music. Differences in age, diversity aspects, and background in gaming were important factors as well, but were not the primary objective here. Many organizations

were contacted in order to reach VIB participants for the design and evaluation phases; The Finnish Federation of the Visually Impaired, the Finnish Deafblind Association, PlayStation Studios and the Royal National Institute of Blind People. Each contributed to providing contact information of VIB for the interviews. Outside of these organizations, the lead author searched for participants on social media through his existing contacts. For the sighted participants, convenience sampling was used to gather participants from LinkedIn, Facebook and a Finnish Discord-community Safepoint. In total, six VIB and six sighted participants participated in this study. Three VIB had a 90% blindness rating by the Finnish medical standards, and one had 50%. Additionally, one participant was colorblind. All were born with the condition except for one born with vision which deteriorated rapidly till the age of 12. Ages were from 32 to 46 as of the interview session, median age being 33.5. All of the VIB had been playing video games since their childhood. One of the VIB identified as female, one as non-binary and the rest as male. Of the sighted participants, one identified as female.

3.3 Original Music Design of Returnal

*Returnal*¹ is a third-person sci-fi-horror game. In *Returnal*, Selene, the heroine-astronaut of the story, emergency lands onto a hostile planet Atropos, discovers herself in a time-loop and starts searching for a signal named 'White Shadow' to solve the mystery of her fate. The original music was created by Bobby Krlic and the PlayStation team and its genre was sci-fi. The musical design for the *Returnal* relied on video game music implementation methods such as layering elements into each other per changing in-game conditions.

¹<https://housemarque.com/games/returnal>

In *Returnal*, the musical state changes from non-combat into enemy-state music inform the players that something has changed and a fight has started. When the enemies are cleared from the area and it can be considered safe again, the musical state changes into a peaceful one, or the music fades away.

The composer Bobby Krlic was contacted asking if he had considered accessibility in his compositions but he did not reply. However online research and readings of interviews about his process revealed that *Returnal* was composed in the same way Bobby composed most of his projects; gathering materials and information about the game, immersing himself in it, and creating without being too specific. According to Krlic: “just press record and play everything for a long time until things seem to be conjuring up the same feeling that I’m getting from the materials” [26].

One way of implementing music in video games is with the following procedure: the music is created in a Digital Audio Workstation (DAW), then imported into the audio engine as separate stems, and finally called from the game engine to play various events that are then triggered by actions visualized in Figure 2.

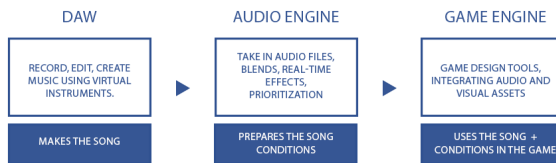


Figure 2: The process of game music composition potentially followed in *Returnal*.

3.4 DSR Phase 1: User-Informed Music Design

3.4.1 Interviews to Inform Game Music Composition. As mentioned, we wanted to explore how the music of *Returnal* could be designed in a way that facilitates greater game accessibility. Hence, we started with interviews with the recruited six VIB and six sighted participants. The interviewees initially were not informed that the study was about game music accessibility, so as not to create any positive or negative bias, but were told that the research purpose was to study video game design in general. Participants were asked permission to record the interviews, transcribe the audio to text, analyze it, and use it in the research.

At the start of the interview, the lead author presented the participants with a gameplay video of *Returnal*, and they were asked for their general impressions of the gameplay. After that, the real purpose of the study was revealed, leading the participants to more specifically discuss *Returnal*’s music and how they perceive it. Next, the participants were shown two other videos from *Returnal*’s gameplay and were asked to specifically reflect on the music in those scenes. The first gameplay video had only sound effects on it, the second only music and the third a mix of sound effects and music but in a different environment. The first two videos had the main character Selene entering combat, shooting and dodging enemy-monsters’ bullets in a hostile alien planet’s forest. In the third video, Selene stood outside a house on the same planet, she then entered indoors and into a tight corridor, which launched a cinematic cutscene.

Video footage was used to showcase the gameplay because it was best to ensure the same material is shown to participants online and in-person, in a standardized manner. One of the VIB participated from the United Kingdom and having the test on-site with an accessible site and a working build of the game was not possible at the time. Another reason was that the game *Returnal* has procedurally generated levels, meaning that the levels are seldom in the same order. Having optimal and similar playing conditions and in-game environments for everyone would have been impossible otherwise.

The interviews were structured through a pre-decided and consistent sequence of questions so that each participant was asked the same questions in the same order. The questions were left open-ended as in ‘what’, ‘why’, and ‘how’. The question themes were Introduction (e.g., personal background, experiences, preferred games), the participants were then presented gameplay video 1 and asked to reflect on it, the real purpose of the study was revealed and the interviews continued with reflections on video 2 and 3 then open conclusion. Through this thematic structure the aim was to find out, how the interviewees feel music can be accessible, informative and guide the player, as well as which features in a gameplay-like situation they would consider disrupting or enabling, and finally, to learn about what could be made more suitable to their needs. The feedback received from this interview round was used as a backbone in determining musical requirements and composing the test compositions.

3.4.2 Findings from Phase 1. In the introduction during the interview phase, all of the participants from both groups reported that they had been gaming since their childhood. Some of the VIB relied on different accessories and services to play games meant for the mainstream audience whereas some had naturally moved to narrative-based games and away from highly visual game experiences. Two VIB played games which were clearly designed for visual stimulus and visual stimulus reactive elements, whereas others relied on strategic games or games in which reactionary speed or visuals weren’t a priority.

Based on their initial gaming experiences, most of the VIB felt music was a disruptive and possibly a disturbing experience, if it would be the only accessibility device without supportive sound effects.

I’m thinking mostly about how I can turn it (the music) off and how I can make the actual sound effects in the game do the things I need them to do. Not so much the soundtrack. It depends on my mood because sometimes the musical pressure can make the whole situation feel worse. (Participant Them/They, 32 years, 90% blind from birth)

It’s extremely rare in the games I play at the moment for music to be utilized in that sort of fashion [to facilitate accessibility]. But it’s not to say it couldn’t be done or be really interesting. (Participant Male, 28, 90% blindness, blind from birth, British)

However, both groups provided counterarguments and specific feedback on how video game music could be made more accessible. The feedback was incorporated into the test compositions aiming to be more accessible, preferably serving both target groups. Below are key pieces of feedback that were next evaluated by the study:

When you are in a real space, there is a scent, or a specific atmosphere, real music and sounds! Meaning the same would

be true in video games— there could be vacuum music in a vacuum, in space, space music, in a forest, forest music [...] if you're in a town center, for example, like, it's believable if you walk past a store or something, almost like you would in real life, and you'd hear kind of the music coming out of the store speakers, or you walk past a pub and you can hear someone playing or these sorts of things. (Participant Female, 46, blind from birth, translated from Finnish)

The Doom soundtrack consists of elements that are brought into the game when the situation demands it. For example, certain enemies have their own instruments that, when they appear, bring that instrument to the front. Even if the enemies are not immediately visible, you can still hear and understand from the music that they have appeared somewhere on the field. (Participant Male, 34, 50% blindness rate, translated from Finnish)

Tempo and pitch changes and modulations could help as well in music; the closer you are to a treasure box, the higher the pitch would go. Stylistically, you can influence the music in a similar way than the game sounds are doing. One game which does this in one mission is Destiny 2: you shoot squares in the sky, you can watch how those ascend but if you listen carefully, you can hear from the tune, which of those you should choose to shoot, you'd save a lot of time by just listening. (Participant Male, 32, color-blind, translated from Finnish)

Overall, VIB recommended that audible musical elements could better reflect the gameplay conditions and serve much more than just as a story-telling device. Different environmental musics, variety and culture, combined with psychoacoustics, psychological and physical elements and auditory effects came evident in the results. The recommendations work to make game music more informative as suggested by one participant:

Could music work, as it is, as an informative tool? Not in a way that wouldn't be super clunky. (Participant Them/They, 32 years, 90% blind from birth, British)

After the interview phase, the transcribed interviews were first summarized. Table 1 provides a summary of how music can increase or decrease the accessibility of games from the perspective of VIB. The transcripts were also analyzed through thematic analysis to identify emergent themes of interest. The identified themes were immersion vs. distraction, provision of functional information, and sound effects over music.

Immersion vs. Distraction: Music needs to balance being engaging and immersive while avoiding causing disturbance to the player. This can be achieved when the music is game genre-related and purpose-relevant, reveals information on time and in the right location of action while being dynamically adaptive and in sync with the game events and thematic game world changes.

Provision of functional information: Especially to be more accessible, the music would need to adapt to elements such as direction, distance and to be adjustable with specific slides by the player. The option to toggle music and effects on and off would be of great value, and also the option to turn on alternatives to the music at specific moments.

Sound effects over music: It is important to have music that works with sound effects so that they support each other instead of having only music or music detached from sound effects or game dynamics.

As for the people with no visual impairment (sighted participants), the target group demonstrated a greater focus on the emotional and narrational aspects of music. To them, visuals provided primary game-scene information. Sighted participants considered music as an immersive tool, while VIB deemed it potentially distracting if it was too loud or aggressive, as they rely mainly on audio for information. Both groups agreed on the need for synchronization between sound effects and music, with some VIB opting to turn off music entirely to preserve informative sound qualities.

After being shown the illustrative videos, the sighted participants mostly described things they visually perceived first, even though they were asked to reflect on music. They noted how the music reflected the visuals such as that it communicated grunts, bending metals, or when a character was close to death. It appears that to them, music had more of a supporting role that might not be adding much beyond the visuals.

3.4.3 Game Music composition. Based on the interviews, the lead researcher composed three pieces of music to test the previously mentioned accessibility recommendations. The first composition was named 'Elements', with 14 layered tracks containing adaptive musical information about the surroundings, enemy location, bullet trajectories, character health condition, enemy deaths, enemy number status, and if the battle was started, ongoing, or ended. Technologies used in implementing them were shepard tone, panning, doppler, tetrachords, rhythmic evolving towards the end of the battle scene, distance based volume automation, reverbs and delays. The focus of Elements was to showcase only informative musical elements, informative being what the researcher deemed of importance to gameplay.

The second composition, 'Flavor' was created to support thematic storytelling in sci-fi horror with the selection of musical motifs and instruments belonging to the genre. These elements related to horror and found in the music of Returnal, were sliding tonality in violins, modular and evolving pads, low drones and dissonances, atonality, clusters of sound and distorted, eroded vocal atonal choirs. 'Flavor' was designed to give a more thematic feeling to the genre and surroundings than a functionality-based approach such as was used with Elements.

The third composition 'Flavor and Elements' combined the previous compositions as those were created to support each other in communicating more information on the immediately happening events along with the thematic elements. They worked as solo compositions, but together gave a fuller understanding of the auditory landscape, the story and the environment. In 'Flavor and Elements', mix and on the spot effects such as side chaining, were added to prioritize more important musical elements while keeping others within auditory reach.

3.5 DSR Phase 2: Evaluation

3.5.1 Phase 2 Evaluation Interviews. After the compositions were ready, a validation round was initiated where these three compositions and the original game track were presented to the same participants from both target groups individually. The time between the first interviews and the follow-up evaluation interviews was more than three weeks. Having some time in between was purposeful, as it allowed the participants to have a more fresh focus

Table 1: Interview findings on how music can increase or decrease game accessibility.

Music that increases game accessibility according to VIB	Music that decreases game accessibility according to VIB
<p>Night and Daytime Cycle. Different themed Map Zones (Plant Zone, Ice Zone) to help the player understand where they are. Music Changing if the enemies are cleared, indicating when attention is needed and when the player can relax. Place and location tied music (walk past bar, mall, station, stores) and enemy or boss tied music. Music that supplements visuals and is in sync. Adjustable Audio, ducking elements per importance.</p> <p>Helping with a sense of scale of the place and the situation. Intensity of the music could increase when the bullets catch the player, the music could be louder if there would be more enemies.</p>	<p>Too loud music. Adding pressure or emotional overload to an already intense situation through music. Unrealistic echoes that distract the player from understanding the space. Relying only on music instead of sound effects and narration.</p> <p>If the music is not in sync with what’s happening. Enemy music which starts to play – then nothing happens in the game!</p>

on evaluating the compositions. The interviewees were presented with four gameplay videos, each with different composition and no additional sound effects. After each video, they were asked which elements in the music helped them perceive what was happening in the game and how the music felt. After this, a comparison phase followed, in which the participants discussed which composition they deemed most informative, accessible and what could be improved upon.

No information was provided about the compositions beforehand and were presented with the videos in a different order to avoid potential biases. Sighted participants were given a Google Form with questions and video links to fill in on their own time and no video slot was booked as they did not need help with the task. For VIB, individual online meetings were held where the instructor provided information about the structure of the form and wrote down their answers with their permission. This was because getting time slots booked for the VIB proved extremely difficult and some required assistance anyway with the form and order of materials.

3.5.2 Findings from Phase 2 Evaluation Interviews. The results were combined and summarized for each composition or video from both participant groups. The key findings are as follows: The original composition received quite negative feedback from the perspective of accessibility. It was considered more of a background mood soundtrack than anything else. However the genre was recognized as horror and sci-fi. This is illustrated by the following snippet from the interviews:

Nothing! It just had that kind of ambience, which, after all this, felt really weak and it was even hard to follow what was happening there. Despite the fact that I had already seen this clip many times and I knew what was going on in it. (Sighted participant, Female, 32, translated from Finnish)

In the Elements composition, the music was reported to be very informative and especially rhythm, drums and effects to be useful. However, participants mentioned that more of a thematic ambience was missing. Enemies, combat stages and other auditory elements were more easily recognized.

The Flavor composition only had the thematic music on it, making it harder for VIB to perceive what was happening in the video.

However, they were able to recognize the genre as sci-fi and that the music indicated when the player was entering and exiting combat. As musical improvements, the participants suggested adding attack indicators, adding or removing instruments depending on proximity to objects, having sound effects alongside music, and changing physical positions of the key elements in music.

Flavor and Elements: This video was evaluated unanimously as the most able to facilitate game accessibility and the most positively evaluated by the participants from both groups. The video was evaluated unanimously as the most accessible and informative, and the one that VIB would prefer when playing the game.

After the videos, the participants were asked to tell which of the versions sounded most suitable, most informative, most accessible and what could make the experience more suitable for them. Table 2 summarizes their answers per video/composition.

Table 3 presents the final verdicts of the participants on the tested videos and their corresponding compositions. After reviewing all the answers, it became clear that the composition having both thematic and functional value together seemed to be the most favored composition. This composition was found to be the most engaging and immersive while also providing important audio cues and information about the game world. The Elements composition which focused fully on the accessibility elements felt less engaging and immersive as it lacked a thematic texturing (e.g., [32]), while the Flavor composition, which had only thematic elements, felt too disruptive and distracting. The composition combining both appeared to be the most effective.

4 DISCUSSION

Participants with vision impairments unanimously reported that music was disruptive to their gameplay and could never be the main game access vehicle, especially in comparison to sound effects. This research set out to discover if game music could be composed differently so that it would facilitate, rather than hinder access to gameplay interactions. Overall, the results indicate three main things: (1) Designing game music without accessibility consideration may not lead to the best game music experiences according to feedback from the participants (2), the combination of

Table 2: Summary of findings from the second round of interviews.

Questions for the videos	Flavor and Elements	Flavor	Elements	Original
Q1: Which elements in the music helped you perceive what was happening?	Rhythm, progression, panning and rising chord progression.	Music made the situation feel desperate.	Constant drums kept the combat feeling. Drums, panning elements, intro buildup, outro salvation.	More background mood soundtrack, Intro and outro, the violin part felt like 'horror action'.
Q2: How did the music feel in this?	Sort of intense, progressive in the sense of movement and intent.	There wasn't that sense of momentum. It felt like there was only background music with "no accessibility hints".	With less music, it's easier to concentrate on "audio hints" like the panning things. Still I miss at least the scoring arpeggios.	Sounded like a classic horror movie soundtrack.

Table 3: Summary of the final evaluation of the tested compositions Flavor and Elements (FaE), Flavor (F), Elements (E), and Original (OC).

	FaE	F	E	OC
Most accessible	6	0	3	0
Not relying on visual feedback	7	0	1	0
Most informative	7	0	2	0
Most suitable	6	1	2	0
Most static	0	2	0	2

both thematic music and layered adaptive music may be the best able to support game accessibility, as suggested in our composition approach, and (3), the use of sound effects alone to facilitate access was less informative, and the use of music alone was deemed the least informative.

Hence, it is important for us to reiterate again how the accessible composition was designed and why it might have been positively received. This composition combined the emotional, genre-specific and narrative elements with elements which react to the player's immediate actions (i.e., reactive music), and elements which musically respond to the environment, including enemies, surroundings, and directions of threats (i.e., proactive music, see [24]). The interactivity of the composition was built to provide information about directions, senses of threat, number of enemies and player health condition along with the states indicating conflict and threats. In other words, treating musical elements with added informativity on top of the thematic narrative musical elements and applied effects reacting to what is happening in an instant. Video games can be made more accessible for the visually impaired by enhancing musical and locational cues, adding variety, musical effects and creating musical feature design.

Such composition also needs genre-specific pointers which can be identified with ludomusicological analysis (e.g., [32]) of different audiovisual genres, as we have been conditioned since childhood to recognize horror, fantasy and sci-fi by their auditory styles. Then, by creating accessible, in-game-movable musical elements that support the thematic setup of a given genre, such guiding elements can work in the same thematic setting while informing players about

chosen threats and, or situations in the game and even more, enhance the game experience in addition to sound effects and design. These, along with the option to toggle certain elements on and off as well on the code side in-game can really make a difference for both user groups. This became evident in the second round of interviews; the accessible composition, especially with the elements and base combined received positive feedback, enriching the soundscape and aiding in accessibility and information. In the different compositions, the ones having most thought elements in both narrative and informational elements in directions and different musical indicators for the phase of the battle, the amount of enemies, revealing the enemy threats and distances and player conditions were reported as the most accessible and helpful.

Haptic interaction control, toggles, sliders, and priority templates should be considered to empower VIB in manipulating the audio mix. With this, careful consideration of musical elements, compositional techniques and auditory effects can ensure harmonious integration with sound effects. Together these can bring advantages related to the everyday action-perception couplings experienced in real-world interactions with the environment. With an aim to integrate music and sound effects in a manner coherently providing interaction-tied information to a player, designers may further consider making use of cross-modal coherence in hearing and understanding actions [13, 22]. A prominent example of such a design approach is called pseudo-haptics [8, 21, 33], deemed here as referring to touch-based or kinaesthesia-based illusions becoming constituted by hearing dynamic audio feedback in combination with the perceiver's own motor activity. In touch-based illusions, mere subtle dynamic changes in audio feedback yield a chance in a perception of the touch surface [18, 20]. Yet another form of pseudo-haptic illusions relates to the ways that dynamically generated musical feedback on body actions is able to co-constitute felt resistances of movement [28]. Such types of auditory informative feedback, being implemented in the interactive game sound, would benefit both VIB and sighted participants.

Moreover, the inclusion of Wagnerian leitmotifs (musical pieces tied to certain characters and situations) can provide information about characters and themes, while additional musical cues for items, conditional changes, and weapon differentiations contribute

to a richer gaming experience. Striking a balance between providing necessary information and avoiding overwhelming auditory input is important, as some elements can be unintentionally overlapping and thus distraught such as screen reader reading aloud text during character dialogues on the overall gaming experience and information comprehension.

Utilizing this framework of game music composition early on in game music development can help create game-specific, musical experiences that inform people with and without visual impairments while enriching the musical soundscape. Aligning accessibility and development in the early design phase is beneficial for budget considerations as accessibility implementations done as early as possible will be more cost efficient than ‘gluing’ it to the more defined product. At the same time these will prove beneficial for future endeavors, given the persistence and increasing need for accessibility conditions over time [23].

While our research did not directly address music co-creation between composers and gamers, we find that our study still highlights the importance of such cooperation and early user feedback. Early user feedback and testing is not just crucial to technical game development, but also to musical and narrative development. We further recommend that such feedback should be obtained from a variety of user groups of different needs. While the feedback we received from sighted participants and VIB was along the same line, it is specifically the feedback from sighted participants that directed us to the composition of a musical piece that better appeals to both groups. Meaningful co-creation can be fostered through discussions involving various accessibility organizations, incorporating insights from studies on lived experiences with specific conditions, and studying social media discussions to learn more from the diverse range of accessibility challenges.

This study is limited by the time and resources that were available for it. The sample size of games with and without visual impairment who participated in the study was relatively small, which may limit the application of the findings to other genres. Future research could benefit from a bigger sample size of VIB and it could be expanded to a larger variety of people with the need for different accessibility implementations such as individuals with motor functioning disabilities, anxiety disorders, and other related conditions. Furthermore, larger-scale studies of the perception of game music among users with accessibility needs through (psychometric) surveys can aid in the development of a generalisable understanding of game music. There are other factors, such as game mechanics and user interfaces, that also play a crucial role in making games accessible to visually impaired gamers. These were not considered in this research. Future research could benefit from experimental studies that explore the isolated and interactive effects of different musical and game elements in combination and separation of each other. The study’s focus on a specific genre of video game (sci-fi) may limit the generalizability of the findings to other genres.

We recommend expanding research collaboration with different size video game companies in the accessibility field if they would show interest in such collaboration, as together they may have a wide scale impact on industry standards. Cooperating could also aid in gaining increased access to research participants and research facilities. However, possible collaboration with different companies means adhering to company guidelines and rules, which could

potentially limit some parts of the research. Some information and conditions could need non-disclosure agreements and other verification methods.

5 CONCLUSIONS

This research set out to discover if game music could be composed differently so that it would facilitate, rather than hinder access. Overall, the results indicate two main things. Firstly, the currently prevailing approach to designing game music may not be the best approach for music to facilitate game accessibility. According to the present research, all participants unanimously found the user-informed music design approach more informative and usable than the original composition. Secondly, the combination of both thematic music and layered adaptive music may be the best able to support game accessibility, as suggested in our composition approach. The use of sound effects alone to facilitate access was less informative and the use of music alone was deemed the least informative. We recommend future research to expand on this work through research with larger sample sizes and with different gamer groups.

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