Developing an inclusive multiplayer rhythm game for visually impaired children

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Abstract

Visually Impaired (VI) children face difficulties in their relationships, especially within groups. Moreover, it is likely for them to been marginalized and discriminated at school. Therefore, they lack social skills, since friendships create context for developing these skills. Inclusive multiplayer (computer) games can consist of a safe space for the VI children to share a playful experience with their peers and friends, even if they are sighted. However, there is a lack of these games for the VI audience. This thesis aims to cover that research gap, and provide *BongoBeats: Tap with me*; an inclusive multiplayer rhythm computer game for VI children in order to assist them to collaborate with their peers. The game was tested in *Bartiméus* school; a special school for VI children, with 16 participants, who played in teams of two. Through the experiment, collected quantitative data were collected regarding the teams score, and qualitative data through interviews and observations regarding the game performance, the teams collaboration, and the game experience of the players. Additionally, two expert interviews were conducted in order to collect more in depth feedback regarding the game and possible next steps. In this thesis, it was found that the VI children generally enjoyed the inclusive rhythm multiplayer computer game and collaborated very well, in teams of two. Furthermore, it is suggested for future research on this topic, to provide enough and discrete audio feedback, and to offer a variety of choices in levels and songs/genres within inclusive rhythm multiplayer computer games for VI children. Further research is needed to ensure that the VI children can play the game also with and against their sighted peers, and to monitor the collaboration and the equality between them.

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Contents

2 Introduction

In the Introduction section, the motivation for the thesis, the problem statement along with its three subsections, and the literature research protocol are presented in that order.

2.1 Motivation

Researchers in the domain of social psychology who have studied Visually Impaired (VI) children have identified several barriers and difficulties in their everyday life, especially in their relationships. For instance, in [50] it was found that the VI children cannot as easily integrate into groups and form intimate relationships as sighted children [50]. However, in the 21st century, there are plenty of assistive technologies that can help VI children to participate in team activities and develop their social skills through them [55, 19]. A common example is video games which are used by 23 million VI people [37]. VI gamers usually play with other VI players, as it is likely for them to have similar interests, but also, because there is a lack of inclusive multiplayer video games that can be played by both VI and sighted players [26, 27].

Nowadays, most of the VI children go to mainstream and not in special schools [42, 41]. In the Netherlands, at least 75 % of VI children go to mainstream schools [66]. So, VI children have sighted peers, and thus, there is a high chance to form a friendship with a sighted peer. However, a study has shown that VI children usually form relationships with other VI peers for two reasons. On the one hand, they tend to understand and support each other as they have the same impairment [56]. On the other, it is likely for VI children to be treated stereo-typically by sighted children, and thus, been marginalized by them [56, 50, 59, 55].

This is not always the case. There are sighted children that show compassion and empathy for their VI peers and support them as much as they can [19, 25]. In [19], it was shown that in physical team activities, VI children were supported by their sighted peers and they were forming relationships with them. Most likely, the same happens in digital team activities, such as multiplayer games. Though, there are no findings to support this, as there is a gap in the literature for inclusive multiplayer video games for VI and sighted children [27].

2.2 Problem Statement

The problem statement is divided into the four following subsections; Visually Impaired (VI) people, Social issues of VI children, Friendships of VI with sighted children, and Lack of inclusive multiplayer games for VI and sighted children. The first contains pure facts about VI people and their impairment. The second goes into detail regarding the impairment of VI children and its consequences, especially in regards to social interaction. In the third, it is explained how important are friendships for VI children, especially with sighted peers. In the fourth, it is taken into consideration important findings from the third, about friendships between VI and sighted children. The reason behind this choice, is to justify the importance of this thesis which will shed light on the literature gap on inclusive multiplayer games for VI and sighted children. These games can help the VI children develop their social skills and feel belonged to groups.

2.2.1 Visually Impaired (VI) people

Visually Impaired (VI) people are divided between Blinds (B) and people with Low-Vision (LV) due to a disease, such as amblyopia, retinopathy of prematurity, congenital nystagmus, ocular albinism, etc. [48]. People with LV, see with fewer colors or/and decreased sight field. Another distinction is between Early Blinds (EB) who were born without sight, and Late Blinds (LB), who lost (complete or partial) sight during their life [49]. Usually, EB have developed compensating abilities, such as a very accurate sense of touch [70], and a good connection between sound and touch [44]. Of course, also LB can develop compensating abilities, it just requires time and practice.

VI people are trained daily in their lives to develop compensating abilities, not just because they want to, but because they have to. For example, to be able to read, especially the Blinds (B), need to learn how to use the Braille system. Braille is the predominant system for VI people to read. The core idea is to read by sensing the texture of raised structured dots [9]. Another daily assistive item that most VI people use is the White Cane. The White, or else, the Long cane is utilized as an arm extension for VI people providing them audio and tactile spatial information regarding objects, walls, and grounds that are around while they are walking [33, 49]. Of course, to collect these audio-haptics cues they tap the objects with the White Cane. As long as, VI people utilize daily tools that focus on sound or/and touch, they develop highly the corresponding senses, and most possibly higher than sighted people [12, 22].

2.2.2 Social issues of VI children

VI people, like every person with a disability, face difficulties in their relationships. One of their most serious issues is the high possibility of being marginalized. People often perceive them stereo-typically and treat them differently than people without disabilities [56]. Especially in schools, VI children are often perceived by their sighted classmates to be outsiders [56]. This makes it difficult for VI children to form relationships with their sighted peers. It is likely for them to be treated as abnormal people and left out of group activities [50].

VI children tend to form friendships with other VI peers, as it is more likely to be understood by them [56]. A study about friendships of VI adolescents [56], has proved that blindness causes difficulties in monitoring large-group social situations. It was found that Blind (B) children usually have one to two (closed) friends, and these are often children with the same disability. Interestingly, children with Low-Vision (LV) have more frineds; two to three on average. Hence, it can be hypothesized that the degree of disability is oppositely equivalent with the ability of handling social situations with a lot of people.

It is very likely for VI children to face discrimination or/and marginalization in mainstream schools [56, 50, 59, 55]. In a study about bullying [7], the 90.9 per cent of parents of VI children reported that their children have been received verbal bullying at least sometimes, and that makes them the category with the highest received bullying, compared to other categories with disabilities and non-disabled children. Bullying usually happens in places and times where there are no adults, such as, in the corridors during the breaks [21, 30].

Bullying not only harms emotionally the children, but also, isolates them [55]. Isolation leads to the lack of social skills, since the latter is developed through daily social interaction, especially at a young age. In [55], they asked students about their childhood bullying experiences, and those that were in isolation and emotional pain,

they lacked the social skills to start and carry on conversations, play multiplayer games effectively, and join and feel part of a group. VI children are slower in learning and developing social skills that are heavily dependent on visual information [59], such as understanding others' feelings. Hence, the earliest they will be able to gain and develop social skills, the better for them. Moreover, the lack of social skills influences negatively the academic performance of children [3].

On a positive note, friendships create contexts in which social skills are exchanged and developed from one person to the other [31, 21]. Despite that, it is usual for VI children to receive bullying in mainstream schools, there is evidence that they have at least one sighted friend, who supports them constantly [61, 19], and helps them to cope with it.

2.2.3 Lack of inclusive multiplayer games for VI and sighted children

Multiplayer games contain team activities, and collaborative tasks which aim for healthy collaboration between the players [10]. By playing multiplayer games, players train their collaborative skills and make friendships [60, 64]. Thus, a multiplayer game seems promising for VI children to cope with their social issues. However, most of the multiplayer games developed for VI players, either cannot be played by sighted players [27], or are boring to them [26]. This is restrictive for the VI children, especially for those that go to "mainstream" schools and they cannot share gaming experiences with their sighted peers.

An inclusive multiplayer game for VI and sighted children must take into consideration the different needs, abilities and interests of VI and sighted children [26]. Even if sighted players are willing to play audio games for VI players, it is likely to lose interest [26]. On the other flip of the coin, VI children avoid to play "mainstream" games with sighted friends to avoid the frustration of not being able to perform well [26].

Nevertheless, there is evidence that VI players enjoying play together with sighted players, even if they have supporting roles [26]. What they care for, is to contribute to the game plot and outcome [2].

Thus, in this thesis an inclusive multiplayer rhythm game for VI and sighted children will be developed. The reason due to which the rhythm genre was chosen is that it is popular and very suitable for VI players [1, 12, 70], because of their sight impairment.

2.3 Literature research protocol

There were three ways, in which references were collected in this thesis. The first was from the archive that was held from the literature review I wrote on inclusive games for VI children [53]. Especially, regarding audio-only and audio-haptics inclusive games for VI children, there were a lot of references in the archive.

The second way was searching through Google Scholar. The keywords that were used were the following; "visually impaired children", "inclusive games for visually impaired children" "inclusive play", "accessibility in serious games", "serious games for visually impaired children", "games for visually impaired and sighted children", "multiplayer games for visually impaired children". "multiplayer games for visually impaired and sighted children", "audio-only games for visually impaired children", audio-haptics games for visually impaired children", "multiplayer games guidelines", "social interaction between visually impaired and sighted children", "game experience

questionnaires". Before downloading a reference, the abstract was read, to assess its relativity to this thesis. Furthermore, there were searches in which there was a year filter, from 2017 and after. The reason behind this filter choice was the need for contemporary studies on games for VI children.

The third way of collecting references was through the two supervisors; Hanna Hauptmann and Anja Volk, and two fellow masters' students; Luuk Schlette and Quentin van Reenen (one from HCI and one from BI masters') with relevant theses topics. With the mentioned peers, and the supervisor Hanna Hauptmann, we were meeting every week and exchanging relevant information about the literature research on both of our topics.

3 Background

This master's thesis is a continuation of [53], and [67] which run under the research pillar of *Dynamics of Youth* of *Utrecht University*. The former, was a literature review written by me regarding inclusive computer games for VI children. The latter was an empirical study that touched upon [53], and two fellow students (one from HCI and one from GMT masters') developed an inclusive rhythm game for VI and sighted children. They tested it with VI children in *Bartiméus* special school [6], and with sighted students from *Utrecht University*. Both participants enjoyed the game.

In [53], I found plenty of arguments [25, 16, 26, 23] supporting the importance of adding a multiplayer function in inclusive games for VI children. Tycho and Lisa did not include one in their game [67], mainly because of time limitation. Though, they let the participants who were coming in dyads or groups watch each other, in order to have a feeling of playing together. The feedback from participants regarding that choice was very promising. Specifically, they noted that it was fun to play in turns and that they enjoyed learning from each others' mistakes.

For this thesis, findings from [53] have been considered, such as, the importance of haptics cues to boost VI players' performance [70, 46], the prominence of multiplayer function to improve players' enjoyment [25], the predominance of rhythm computer games as a genre for VI players, and the lack of inclusive multiplayer games for VI and sighted players [27]. These findings were also empirically supported by [67]. Therefore this thesis, is an extension of [53] and [67], having as a goal to shed light on the social interaction between VI and sighted children in inclusive multiplayer video games.

4 Related Work

In this section, the related work is presented. In the first subsection, the concepts of inclusive play and accessibility are explained, and the corresponding requirements and guidelines are given. Following, there is a definition for serious games, along with a listing of the basic practice areas of the field. In the third section, it is explained what is needed for a fair gaming experience between VI and sighted children, and then corresponding examples from previous work are given. The fourth section is about computer games for VI players and it includes examples of previous work along with their characteristics. Finally, the fifth section is in regards to multiplayer computer games for VI and sighted children and it is subdivided into social interaction, examples, and guidelines.

4.1 Inclusive Play and Accessibility

According to [55], acts, and activities that can enhance the social skills of VI children are the following: participate actively as a member of a group; solve problems in a team effort; help others, and not only being helped; gain attention, initiate and maintain conversation; develop strategies to cope with conflict; express feelings and understand others' feelings; understand others' perspectives; develop self-esteem and confidence.

All the above are requirements for inclusive play. Play is a way of understanding and a way of explaining [28]. Inclusion is the act of including, and frequently is used for sensitive audiences, such as disabled children. Therefore, inclusive play for disabled children consists of playful activities that can be enjoyed by both disabled and non-disabled children. These activities are designed to include disabled people, and thus, their abilities, needs, and interests are taken into consideration.

A common means for inclusive play are multiplayer games. Through rules, organized play, a safe environment, and the option of playing together, multiplayer games have the potential to provide equal play experiences to sighted and non-sighted people.

Some basic guidelines that must be met for providing a safe and holistic inclusive play experience to disabled children are the following [63]: 'creation of a rich mix of play opportunities, the engagement of the senses', 'the availability of different types of space', 'the consent from parents and families, and the 'accessibility'.

Accessibility means to make play accessible to everyone regardless of abilities or age [43]. A paper published for the 4th Symposium of the Workgroup HCI and Usability Engineering [43] developed guidelines for games accessibility that were based on two previous similar projects: one from IGDA, the International Games Developer Association and one from the Norwegian IT company MediaLT. The guidelines consisted of five categories and three classes of priorities. The categories were level and progression; input; graphics; sound; and installation and settings. The classes of priorities were the 'must have', the 'should have' and the 'may have'. The categories and classes of priority are dependent on the type of disability. For the VI category, sound, input, and installation and settings belong to the 'must have' priority class, the level and progression to the 'should have' and the graphics to the 'may have' in case there are people with Low-Vision that can see.

4.2 Serious Games for VI children

Games are the structure that is applied to play based on organized rules [28]. Serious games are games designed for a primary purpose other than "pure entertainment" The main areas of practice for serious game are education & learning, healthcare, training & education, and marketing & advertising. The game of this thesis belongs to the education & learning area as it concerns a game developed for VI children to teach them social skills through collaborative role-playing tasks.

4.3 Gaming experiences between VI and sighted children

In order to make an inclusive serious game for VI players, accessible to sighted players, they need to be considered the needs, abilities, and interests of both groups. Furthermore, a successful inclusive game for VI and sighted children, should include tasks and objectives which teach about inclusion itself [41], pushing sighted children to see through the eyes of their VI peers. That will help them to see how it is to live with sight impairment, and therefore, to feel empathy and compassion for their VI peers.

On the other flip of the coin, barriers that sighted children might face when playing inclusive games for VI players, should be prevented. An example of problems that sighted players might face in games for VI players is the difficulty to interact with complex hardware that provide tactile feedback. In [38], some sighted players could not use smoothly the tactile hardware, maybe because they were not familiar with haptic feedback, as their VI peers are. Another example is that they interpret and complete the game faster than VI players [2, 69], and that might cause them boredom.

There are promising findings concerning fair play potential between VI and sighted children in games. In [25], and [38], VI and sighted children enjoyed similarly the corresponding games. From the angle of challenge, it was found in [70], that after half an hour of practice, the level of challenge was perceived the same from VI and sighted players. In terms of experience, it was shown in [65], that VI players interpreted the game story just like the sighted players. Moreover, in [66], one of the few studies on inclusive multiplayer serious games for VI and sighted children, was found that VI and sighted players showed similar play and social behaviors. This is in line with the findings of [18] concerning the comparison of sighted and VI children in social interaction. In [18] was shown that VI children enjoy to play and interact with peers as much as other children.

VI and sighted children not only are able to play together, but also, they are willing to. In [25], when sighted participants were informed that the game is addressed mainly to VI players, they were more than happy to help them by taking place in the experiment. Actually, one of them showed solidarity by playing blindfolded.

Finally, characteristics that are suitable for an inclusive multiplayer game for VI and sighted players, are narration and role-playing. Recently, it was shown in [41], that role-playing helps VI and sighted children to execute group tasks successfully with order and precision. In addition, in [41] the narration was helping the VI children to catch up with the game flow and story and was boosting the sighted players' engagement and interest.

4.4 Computer games for VI players

As this thesis specifically focuses on computer (rhythm) games for VI children, suitable examples from related work are given in this section. It is subdivided into two subsections regarding the cues that are used; audio-only, and audio-haptics, and one subsection about the genre of the game; Rhythm computer games. In the last paragraph of every section it is mentioned which characteristics from previous work will be utilized in the game of this thesis; BongoBeat: Tap with me.

4.4.1 Audio-only computer games

Audio-only games, as the name says, provide solely audio cues to the players. Mainly, audio-only games, use 3D sounds [15, 54] to inform players regarding spatial information of objects and enemies, discrete (distinctive)) sounds [13, 14, 47] to notify them regarding precision matters, natural sounds [54] to immerse them, background music [13, 14, 54, 25, 70] to entertain them, and score sound [13, 14, 47] to keep them updated about the outcome of the game.

An example of a study in which audio-only computer games for VI were developed, is [54]. There were developed three actions and one adventure game to investigate the technical perspective and the aesthetics in the design of audio-only computer games. Since the study took place in 2005, old-fashioned hardware, such as, a head-tracking

device, a stylus pen, and an EyeToy were used. A technique that was used to challenge the players was to increase the loudness of background music as levels were increased.

Another example is [13], which was specifically developed for observing and investigating the gaming behaviour of VI players. Classic audio features for inclusive games for VI players, such as score sound, discrete sound, and background music were used. However, 3D sound was not utilized and almost all the participants complained about it, as they could not know from where the enemies were coming.

One of the most recent studies for audio-only games for VI players is [47]. The goal in [47], was to develop and evaluate an accessible version of a 'mainstream' educational game. In order to make the game accessible to VI players some sound design techniques were used. An example of such technique is the use of the stereo-panning effect to lateralise the audio and facilitate game events identification. Results were promising, indicating that the accessible version can provide equivalent experiences to VI and sighted players. Nevertheless, there were some technical limitations with the adopted engine, which could not support or update some game resources.

Taking into consideration the related work on audio-only games, I will use in *BongoBeats: Tap with me*, 3D sound, background music, score sound and feedback sound. The 3D sound will be utilized for the notes, indicating the direction they are coming from. In the background, it will be played a song with drums from which the notes are provided to the players in 3D form. The score sound is important to keep the players motivated by remembering them that there is a competition between the teams. For feedback sound, a discrete sound will be used, such as, in [13, 14, 47], to inform the players about the outcome of each note hit. If players will hit successfully a note, then a drum sound combined with a smash will be played, whereas a just the drum sound will be played when a note will be mishit. The reason to use discrete sound is to prevent any misunderstanding from the players.

4.4.2 Audio-haptics computer games

Audio-haptics games provide a combination of audio with haptic cues, such as, vibrations through controllers [1, 15, 46, 70]. Vibrations, with their intensive nature, keep constantly alert the VI players, and provide them extra feedback regarding the game plot and tasks. Despite that, there is evidence that vibrations can boost players' performance [46], sometimes might add complexity with non-robust UI [14, 15, 54] or difficult to learn equipment [70]. For instance, in *Blind Hero*, in which vibrations were provided to the players through a haptic glove to inform them that soon they have to hit the notes, several participants faced difficulties with the glove usage in the first half an hour.

Other equipment, that has been used in audio-haptics games for research, are straps in wrists and hands with small cheap and durable vibrators [1]. The game they developed in [1] was also a rhythm one. The vibrations were informing the players about the outcome of their moves.

A contemporary research on audio-haptics game [38], utilized a big tactile game controller, the TactCon. Vibrations sensations were provided to the fingers through touching the vibrotactile display. The vibrating pins on the display were arranged in a matrix shape having the distance of 2 mm, which is similar to the dot-to-dot distance of Braille characters. Thus, VI players, especially the ones with gaming experience, could handle easier than the other players the tactile display. Most of the complaints for the TactCon were from sighted players, about its large size and heaviness.

A quite common hardware for haptic cues in games for VI players, is the Wiimote

controller [15, 25, 46], coming from the Wii console, a classic console which provides haptics cues. The Wiimore has double usage. While vibrations are provided through it, also features as an extension of the arm for big and flexible moves from the players. Another advantage of the Wiimote is its cheap price, compared to other equipment, such as, the glove in *Blind Hero* [70]. However, there might occur some issues with the interface of the Wiimote, and more specifically, with the recognition of players' movements. For example, in [25], participants reported problems with orientation and navigation as some of their movements were not recognized.

A modern hardware for vibration is HTC Vive, a VR setup for VR games. HTC Vive contains two VR controllers, a VR headset, and two base stations for tracking. It was utilized in [67], without the headset, and any participant reported frustration or any issue with it. Thus, it seems that it is more efficient in terms of movements' recognition than the Wiimote. Besides, it is light and small, and thus, most likely is easier to use than heavier and bigger hardware, such as, the TactCon [38].

In *BongoBeats: Tap with me*, I will use the controllers from the HTC Vive setup. Furthermore, feedback from participants from related work will be considered. More specifically, there will be a practice round to get to use the controllers. Apart from beginners who surely will need time and practice to get to use the controllers, also sighted players, independently from their experience, might be slower than the VI ones, because they are not so familiar with tactile equipment and feedback, as the VI players are.

4.4.3 Rhythm computer games

Rhythm games are one of the predominant genres for the VI audience, and this makes a lot of sense. VI children spend a lot of their daily routine focusing on sounds, and thus, their hearing sense is developed [12]. VI children, are also able to develop good rhythmic skills fast with the suitable mean [65], such as, rhythm games. Besides, the impairment of sight forbids them to watch movies and play games with visuals, and thus, what mainly attracts them in entertainment, are the sound and the music. According to [1, 12, 70], rhythmic games are particularly suitable to VI children, as they already rely on audio as major feedback mechanism [70].

Examples of rhythm games have already been given; *Blind Hero* [70] and *Rock Vibe* [1], two games for VI that have been inspired by the mainstream games *Guitar Hero* and *Rock Band*. In *Blind Hero*, guitar notes were going toward the players from the right or the left, while a song was playing in the background. VI players wore a haptic glove while playing, through which they were vibrating when a note was coming. All the players, were provided with the 3D sound of the notes through headphones, to know the direction of the note coming. *Rock Vibe's* gameplay was very similar to *Blind Hero*, although the equipment was different. The vibrations in *Rock Vibe*, were coming through small vibrators placed in a bracelet that was worn on wrists and hands, while the players were hitting with sticks the drum equipment. As in [67], discrete sounds were used for feedback score. If a note was hit successfully, a drumming sound was playing, whereas a beep sound was playing if the note was mishit.

Another example of a rhythm game for VI players, is AudiOdyssey which was implemented for a masters' thesis at MIT in 2008. Players had the role of the DJ, and as instrumental tracks were playing, their task was to hit at the right direction when the beat was dropping. 3D sound was used to indicate the beat direction. As in *Rock Vibe* [1] and *BongoBeats* [67], audio feedback was given in every hit regarding the outcome. AudiOdyssey can be downloaded for free through [35].

Considering, the related work in rhythm games for VI players, discrete audio feedback will be used in *BongoBeats: Tap with me*. Moreover, as it is stated in [1], the audio feedback apart from discrete, must be also discrete, so that players will not be distracted. Additionally, almost every rhythm game, combines the haptics with audio cues, to give an extra clue to players, and more specifically, to indicate to them the correct timing to hit a note [1, 70, 25]. Hence, in *BongoBeats: Tap with me*, I will use vibrations through HTC Vive controllers, such as in [67], to prepare the players to hit a note that is coming, at the right timing.

4.5 Multiplayer computer games for VI and sighted children

There are four subsections here concerning multiplayer games; one in regards to the social interaction aspect, one with examples of inclusive multiplayer games for VI (and sighted) players, and two with important guidelines that will be taken into consideration in the development of *BongoBeats: Tap with me*; one regarding game heuristics and one concerning game mechanics.

4.5.1 Social interaction

Since there is a lack of multiplayer games for VI players [27], data about the social interaction of players were gathered from studies on multiplayer games for non-disabled players, that focus on group dynamics. According to [10], the most experienced players are dominating their groups in communication and decision-making. This finding is supported by [32], in which was found that the background gaming experience of the players, highly affects the communication patterns of the team on collaborative problem-solving tasks in multiplayer games. Thus, it seems that a single person, depending on his/her experience, can have a major impact on collaboration efficiency and game outcome. Furthermore, an interaction effect was found between gaming experience and prior social ties. It is more likely for an experienced player to dominate the discussion when she plays with people she knows, than when she plays with strangers [10]. This is aligned with [5], a study in which was found that friends are more comfortable than strangers talking and exchanging ideas when they are on the same team in a game.

Multiplayer games, can provide a shared environment for healthy collaboration and social interaction, especially when it is occurred in a pedagogically meaningful context [10]. It is crucial in multiplayer games, to design tasks which require equal participation from all the team members. Collaborative tasks, help the players to develop collaborative skills, and to create meaning through collaboration [60, 64]. In contrast, unequal participation in a team affects negatively the players' understanding of collaboration, and interpretation of the game [10]. Furthermore, the engaging nature of multiplayer games, makes them a safe environment, and, if the game tasks have been designed carefully, positive collaborative interaction will surely occur. There are examples, in which players were so immersed and present in the game, that their team and the game world were the most valuable things they had at these moments [62]. That gives hope for increasing the sense of belonging of VI children through multiplayer games.

In a recent study [11], about Multiplayer Online Battle Arenas (MOBA), was found that social interaction was the highest motivation to play a MOBA. However, not all players play MOBAs to socially interact. Players who prefer solo games than

party matches, play MOBAs to compete with others. In contrast, players who prefer to play party matches, play MOBAs to socialize. Thus, both competitive and collaborative game characteristics are important to motivate different kinds of players. It is hypothesized here that these findings apply also to inclusive games for VI and sighted children.

4.5.2 Examples

Kinaptic [27], the first accessible game for fair competition between VI and sighted players developed for research purposes in 2016. Kinaptic is an audio-haptics game taking place in a 3D enviroment with collaborative and competitive features. In Kinaptic, an asymmetric setup was used. The blind players played with an audio-haptic setup and the sighted players played with an audio-visual setup. Moreover, asymmetric group tasks were used, in which players played in turns. It was found, through [27], that VI players were motivated to play the game again, especially with sighted opponents. That finding confirms [19], a study in which was stated that VI are keen to compete with sighted peers and friends more than with VI ones, in team activities.

Another multiplayer game for VI and sighted players, is WaTa Fight [23], a competitive casual party fighting game. Wata Fight is a mobile game, in which two players play against each other by trying to tap on a smartphone screen faster than the opponent, in order to perform an attack. The results in [23] that were derived through focus groups and a survey were very promising. On the one hand, all the participants showed openness and sympathy for the other players during the game. On the other hand, the VI players showed a big interest to play again and especially with sighted opponents. Multiplayer games, either competitive or collaborative, can be very promising, not only for helping the VI children express themselves, but also, for sighted ones to empathise with them [23, 41].

A common feature for multiplayer inclusive games for VI and sighted players, is asymmetry. VI players need more time to interpret information, and therefore, to complete their actions [2, 69]. Thus, the ability to take their time without pressure, will lead to a fair winning chance between them and the sighted players [27]. The VI participants in [26], indicated their desire for more asynchronous digital games.

A recent asymmetric inclusive research game for VI people was developed in 2020 [16]. Participants were only VI players and they were divided into dyads, in which there were two roles; the guide, and the explorer. Explorer was interacting with a Tangible User Interface (TUI), and the guide was giving him/her spatial information and play instructions. It was found, that not only, VI players enjoy collaborating with each other, but also, they trained and enhanced their spatial skills, while they were solving complex spatial tasks by role-playing. It is important to note here, that VI players use more the egocentric than the allocentric representation to describe space and navigate into it [17]. That means that they describe and move to space, based on themselves and not on the compass. Besides, this is the reason they use the terms 'right' and 'left', instead of 'east' and 'west'.

4.5.3 Heuristics

One of the most predominant game heuristics for multiplayer games is the Networked Game Heuristics (NGH) [51]. NGH is derived from real use cases and has been evaluated and compared with Baker's groupware usability heuristics [4], which are based on the mechanics of collaboration [29]. In contrast, NGH focus on multi-user aspects

of the design, rather than usability issues. From the evaluation, and the comparison of the two Heuristics sets, it is concluded that NGH [29], cover specific game issues that are not covered by Baker's Heuristics [4]. The latter focus on heuristic evaluation using groupware heuristics for identifying teamwork problems in shared workspace groupware systems. In addition, NGH can be applied easier, as there is more clear pairing between the features and the game interface than in the Baker's Heuristics [4]. The heuristics, along with solutions to key issues that can be derived, which will be considered in the game development can be found in Table 1. However, four out of ten heuristics were left out, as three of them are not relevant to a research game, and one is not relevant to a rhythm game.

4.5.4 Mechanics

A design approach, with suggested game mechanics for multiplayer games, which is relevant to this thesis, is [68]. This approach focuses on collaborative learning scenarios in serious multiplayer games. It takes into consideration, the requirements of traditional single-player games (fun, narration, immersion, graphics, sound), multiplayer games challenges (concurrent gaming, interaction), and serious games design (seamless inclusion of learning content, adaptation and personalization). For testing the collaborative scenarios in a multiplayer serious game, a collaborative 3D virtual world; the Wilson Island, was created [68]. Thus, through evaluation it was observed that the suggested game mechanics lead to the utilization, and therefore, the development of social skills, such as, teamwork, coordination, and communication. The game mechanics, along with their descriptions, which will be taken into consideration in the game development can be found in Table 2. Because *BongoBeats: Tap with me*, belongs to the rhythm genre, the game mechanics 'refillable personal resources' and 'trading system' were left out, as they are irrelevant to that genre.

5 Research Questions

There are three main goals for this thesis; a) to ensure that an inclusive multiplayer rhythm game can offer a fair winning chance to Blind and Low-Vision players, to b) to investigate how VI players perform, collaborate with their teammates, and experience the game in *BongoBeats: Tap with me*; an inclusive multiplayer rhythm game. To achieve the first goal, the score performance of the teams is measured quantitatively and then it is compared between the group categories; the Blind, the LV, and the mixed teams (one blind and one LV player). Concerning the second goal, the game performance, the teams collaboration, and the game experience are measured qualitatively from the perspective of observers (during the experiment), but of course, also from the perspective of the participants (through interviews). More details on how the game performance (RQ1.1) the teams collaboration (RQ2) and the game experience (RQ3) were measured qualitatively can be found on the Methodology section.

The Research Questions (RQ), along with the sub-questions are the following:

RQ1: Which teams did score higher in BongoBeats; Tap with me; an inclusive multiplayer rhythm game, the blind teams (two blind players), the Low-Vision teams (two players with Low-Vision) or the mixed teams (one blind, one LV player)?

Ho: There is no significant difference on performance between blind, LV and mixed teams in an inclusive multiplayer rhythm game.

Table 1: Networked Game Heuristics (NGH) for Multiplayer Games [29]

Heuristics	**Avoiding key issues**
Manage bad behaviour	Games should provide by default solutions to bad behaviour such as cheating, violation and discrimination. For instance, players who do not follow the rules and behave inappropriate should be banned from the game and the game servers.
Appropriate communication tools	Channels that are easy to use by every player and do not consume plenty of resources should be utilized to give the ability to the players to communicate with each other the fastest and the easiest as possible. A common example is Discord.
Support coordination	Designers and developers should design and implement shared tasks and activities that need input and collaboration from all the players of the team.
Support social interaction	Designers and developers should design and implement tasks and activities that require communication between teammates and group decision making.
Meaningful awareness information	Games should provide players with the necessary information in order to comprehend the game, and the suitable means and space areas to present them in order to be easily accessible.
Training for beginners	Games should provide training rounds for everyone, especially the new players and the beginners. Thus, through training the level difference between teammates and opponents is reduced and the winning chance is more fair for everyone

Table 2: Game Mechanics for Multiplayer Serious Games [68]

Game Mechanics	**Description**
Common goal/Success	A defined shared goal that can be achieved only if all the players coordinate successfully and with good teamwork
Heterogeneous resources	Each player should have unique resources that allows him/her to have his/her own unique contribution
Collectable and tradeable resources	Resources that are collected within the game which affect the game plot, and may be traded between teammates, but also, opponents
Collaborative tasks	Tasks that require (asynchronous or synchronous) collaboration between players
Communication	Communication is more than necessary in Multiplayer games. It is occured either through voice, or through messages in the chat. The predominant channel for communication, in any kind of games, is Discord
In-game help system	A system within the game environment, which offers help to the players that are lost. It should be visible and accessible to everyone, especially to beginners
Scoreboard	A scoreboard is a graphic or/and audio feature, which shows/announces the game score. It gives informational feedback to the players regarding the game plot, and also motivates players to try harder in order to beat their opponents

RQ1.1: How did the Visually Impaired (VI) children perform in BongoBeats; Tap with me; an inclusive multiplayer rhythm game?

RQ2: How did the Visually Impaired (VI) children collaborate in *BongoBeats: Tap with me*; an inclusive multiplayer rhythm game?

RQ3: How did the Visually Impaired (VI) children experience *BongoBeats: Tap with me*; an inclusive multiplayer rhythm game?

6 Methodology

The subquestions within the Methodology section are the following; Participants, Research Methodologies, The game, Game heuristics, Game mechanics, and Data collection.

6.1 Participants

The demographics of the participants who took place in the experiment can be found in Table 4. Sixteen participants were interviewed about their game performance (RQ1.1), their team collaboration (RQ2) and their game experience (RQ3). For the RQ1 (teams score), three teams, and four participants out of sixteen were excluded. One team and the two players that consisted it, was excluded, because a technical issue occured during their game round, having as result to stop suddenly the game. The other two participants were excluded from RQ1 (teams score), because they both came to play with two other pupils. Thus, one pupil from two trios that came together, played twice. The second teams from the two trios was excluded from the RQ1 results, as one of the two players of the team was playing for a second time. All the participants are pupils in the *Bartiméus* school aged from 10 to 17, apart from participant 2 who is a 28 years old volunteer in the school, who is a game master (see pre-last row in Table 13).

The participants played the game in teams of two, or else, in dyads. There are two reasons for choosing dyads and not larger teams. Firstly, it has been proved that VI children usually have one good friend, as they face difficulties belonging to (large) groups [56]. Secondly, the design choice was inspired from [16], if not the only one, one of the few studies on teams collaboration in games for VI children.

6.2 The game

BongoBeats: Tap with me is an inclusive multiplayer rhythm serious game. Inclusive, as it is targeted mainly to VI children, serious as it has the potential to teach social and rhythmic skills to the players, multiplayer as it requires two players to form a team in order to play, and rhythm, due to the game genre. It is also considered an accessible game, as it is not only for VI children, but it can be accessible from sighted children, as well.

BongoBeats: Tap with me is an extension of *BongoBeats* which was developed in 2021 by two colleagues from Information Science department of *Utrecht University*, Tycho Zaal and Lisa Wagensveld for a small project [67]. The game was inspired by BeatSaber a famous VR game in which you smash notes with sticks that you handle with the VR controllers. Thus, in BongoBeats while a song was playing in the background, the objective was to hit as many notes as possible upon two Bongo drums with

the sticks that were handled by two HTC Vive Pro Controllers. In *BongoBeats: Tap with Me* some game features, such as the electro-swing song *Butterfly* by *Swingrowers*, and the use of Bongo drums, and drumsticks, as well as the game concept have been taken from *BongoBeats*. It is important to note here that in [67], immersion of plenty of participants was perceived through the electro-swing song. This is the reason behind the choice to use the same song as in [67]. As *BongoBeats: Tap with me* is a multiplayer game, the suitable game heuristics [51] and mechanics [68] have been considered, and implemented. The game was developed in Unity using the version 2020.3..22.f1, and the HTC Vive Pro Controllers were used for the haptic feedback (vibrations).

Concerning the game roles, they were inspired by [16], and hence, the game was played in teams of two. The one player had the role of the guide, and the other player had the role of the performer. The game had two rounds, so that the players play in both roles. While both of them were receiving spatial audio feedback to be informed if a note has been hit successfully, the guide was also receiving informational feedback early enough to alert and prepare the performer to hit a note in the right direction, at the right timing. The task of the performer was to hit the (left, right, or both directions) notes by handling the drum sticks with the arrow keys of the keyboard, after she has been informed from the guide. If the guide was a child with LV, then she could choose whether she will receive visual informational feedback, through the computer screen, or haptic informational feedback through the HTC Vive Pro controllers. They all chose the audio-haptic setup, and thus, they all played with the HTC Vive Pro controllers to receive vibrations. In order to not receive visual cues, the LV participants had to wear a face mask in both roles (see Figure 6 in Appendices). The haptic feedback were vibrations that were coming through the HTC Vice Pro controllers for 0.3 seconds and were a signal that a note is coming, from the left, the right, or both directions. On the other side, if the guide was a blind child, then she had only the option of receiving haptic feedback, as she was not able to see.

The main objective of the dyads was to collaborate in order to hit every drum note, at the correct timing. There are no strict rules for dyads' collaboration, as long as players stick to their roles. Of course, directions were provided right before the experiment, and right after the directions, the participants had time for a practice round to get familiar with the game.

A screenshot which shows the visual elements of the game can be found in Figure 1. Photos from the experiment, with the teams playing the game can be found in Appendices (Figure 5, Figure 6, and Figure 7).

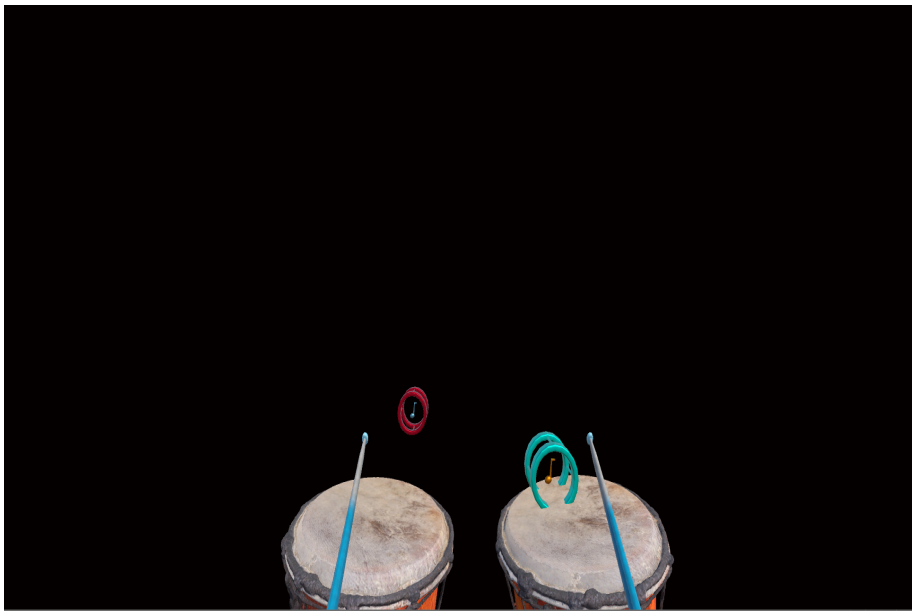

Figure 1: A screenshot from the game showing the visual elements.

6.3 Game heuristics

The game heuristics of [51] have been taken into consideration for the game development of *BongoBeats: Tap with me*. The reason for this choice was to ensure that the game complies with basic guidelines for multiplayer games. To 'manage bad behavior', such as cheating, participants are monitored tightly, especially the ones with LV when they played blindfolded. To 'support coordination' and empower 'social interaction', collaborative tasks are utilized through role-playing. Moreover, collaborative game mechanics inspired by [68], such as, 'heterogeneous resources' and 'communication' are embedded in the game. To provide 'meaningful awareness information', the proper information regarding the game objectives were given right before the experiment. Finally, before every game, each dyad had the option to play a trial round, to get to use the game environment. More details on the game heuristics [51] that took into consideration for the game development can be found in Table 1.

6.4 Game mechanics

Regarding the game mechanics, the framework of [68] was used, as it focuses specifically on multiplayer serious games, and therefore, it is suitable. The game mechanics framework [68], along with descriptions, can be found in Table 2. Concerning, 'common goal', it is present in the game through role-playing, which forces the two players to play collectively as a group to win the game. The game contains a 'collaborative task' which is the directions' provision from the guide to the performer. The guide was provided with an extra (haptic or visual) cue which signifies that a note is coming and she had to inform the performer at the right timing to hit the note. As there

was a 'common goal', and a 'collaborative task', it means that players needed good 'communication' to complete the latter and achieve the former.

Concerning 'heterogeneous resources', different types of cues and information were given to the players, depending on their role. The extra resource that was provided to the guide was a haptic or a visual cue, depending on whether she is blind, with low-vision, or sighted, informing them that a note is coming. The 'collectable resources' in the game was the score that was increased every time the performer was hit a note successfully (in the right direction, at the right time). An audio-visual 'scoreboard' was planned to be utilized to inform the players about their performance and also to motivate them. Unfortunately, there was not a 'scoreboard' in the game, because the last phase of the game development was busy and the focus was on major things, such as the change of the experimental setup (see 7.1, Experimental setup changes). However, the lack of it had a negative impact on players' motivation. This can be understood though a participant's comment which can be found in the last column of Table 8.

Finally, there was no 'in-game help system' as a game mechanic, but I was there to provide help to participants who needed it. For example, a participant under the role of the performer could not reach immediately the arrow keys, and I helped him to find them. It is shown through the image in Figure 7, that I was close to the players in order to help them if it was needed.

6.5 Data collection

Starting with RQ1, which concerns the teams score, each team's score was tracked from a script in Unity and parsed into an excel file. Like in every other rhythm game, such as *Blind Hero* [70], every time the player hit correctly the notes the team earned points. In *BongoBeats: Tap with me*, the points for each successfully hit note equals to 3. The total possible points for a dyad equals to 300. The score of each team was tracked to compare the Blind, the Low-Vision, and the Mixed teams (with one blind and one low-vision player).

As for RQ1.1 (game performance, from a qualitative aspect), RQ2 (team collaboration), and RQ3 (game experience), both structured interviews and observation methodologies were used to collect qualitative data. The reason for which both interviews and observation were utilized as data collection methodologies was to collect both the perspective of the pupils on their game performance (RQ1.1), collaboration (RQ2) and game experience (RQ3), but also the perspective of four observers who have knowledge on the topic of serious games. Thus, on the one hand the participants through the interviews gave their opinion on how they performed in the game, how they collaborated with their teammates, and how they experienced the game. On the other hand, the four observers noted down, as the experiment was running, useful conclusions which were obtained from social cues, facial cues, short conversations with the participants and other signals. Since one of the observers conducted also the interviews, and hence, some of the observations he made were based from there.

For the RQ2 (teams collaboration), the Meier's handbook [39] was used to form the corresponding questions for the structured interviews. Meier created a rating scheme for assessing the quality of computer-supported collaboration processes. Meier's handbook has been utilized frequently in the serious game field, and some examples are [16, 45, 36, 24]. Meier's handbook core is based on nine qualitative dimensions of collaboration to be rated within a collaborative environment or/and task. These are sustaining mutual understanding, dialogue management, information pooling, reaching consen-

sus, task division, time management, technical coordination, reciprocal interaction, and individual task orientation. There were two reasons behind this choice. Firstly, to form nine questions, one for each Meier's collaboration dimension (Questions 1 - 6 & Question 8 - 9, see Table 3). Secondly, to rate the participants on each collaborative dimension based on their answers, and then to count the average score in each dimension, in order to have a supplementary data analysis methodology which shows in numbers how the players collaborated with their teammate. Each dimension, was assessed based on a 4-point Likert scale (from -2 to +2), like in [16, 45, 36, 24]. The grade was put by Luuk Schlette, a Dutch colleague, who conducted the interviews in Dutch. The reason behind this choice, was to give the option to the pupils to be interviewed in their native language.

As for the RQ3 (game experience), the questions that were asked were based on a mix of the Game Engagement Questionnaire (GEQ), and the Player Experience of Need Satisfaction (PENS) questionnaire [58]. The latter [58], is based on Self-Determination Theory [57], and describes the way in which game experiences satisfy universal needs in humans, such as competence, autonomy. In contrast, GEQ [52] is not based on a theory, but on conceptual accounts of player experience and focus groups with players. After a comparison of these two which was made by [34], it is concluded that these two questionnaires can be merged, since some of their dimensions seem to overlap. The six dimensions that by empirical support measure unique items [34, 20] are flow (GEQ), immersion (GEQ), competence (GEQ and PENS), positive affect (GEQ), presence (PENS), and autonomy (PENS). Six questions were asked in the structured interviews regarding game experience, one for each game experience dimension (see Question 10 - Question 15, Table 3). Such as for RQ1.1, and RQ2, also for the game experience of the players (RQ3), the observers' perspectives were collected. Apart from the answers of the participants, and the comments of the observers, ratings on each of the six GEQ and PENS game experience dimensions were given to the participants by Luuk, in order to show in numbers, through the average score, how the players experienced the game.

Table 3: A table with the Interview Questions.

No:	Question	Variable	RQ
1	How well do you think you divided the tasks? task division	task division	2
2	How well did you manage to understand the game and each other?	maintain mutual understanding	2
3	When you had the guide role, did you give all the necessary (and no more) information to the performer? And, when you had the performer role, did you get all the necessary (and no more) information from the guide?	information exchange	1.1, 2
4	How well did you manage to understand each other's questions and sentences? Do you think your dialogue during the game was efficient?	dialogue management	2
5	How equal do you think your contribution to the game decisions was?	mutual interaction	2
6	How efficiently do you think you handled time during the test and rounds of play?	time management	1.1, 2
7	To what extent do you think the performer followed your instructions when you had the guide role?	competency	3
8	When needed, how well did you manage to coordinate on the technical part? For example, if one of you needed help with the controllers or keyboard, was the other able to help him?	technical coordination	2
9	Did you have any motivation while playing, and if so, what was it?	individual task orientation	1.1, 2
10	How easily did you manage to reach consensus when you had to make a decision during the trial and game rounds?	reaching consensus	2
11	How independent do you think you were during the game? Do you think you were free to make your own decisions?	autonomy	3
12	How much were you absorbed in the game world while you were playing? Were you thinking about anything other than the game objective?	immersion	3
13	How focused were you on the game while you were playing?	flow	3
14	Do you think the game positively affected your mood, and if so, to what extent?	positive effect	3
15	How present were you in the game world? Was your attention distracted by sounds or thoughts?	presence	3

Table 4: Participants Demographics

Variable	**RQ1**	**RQ1.1**	**RQ2**	**RQ3**
Participants	12	16	16	16
Age	10 - 17	10 - 28	10 - 28	10 - 28
Age average	13.25	14.25	14.25	14.25
Gender	1F, 11M	2F, 14M	2F, 14M	2F, 14M

The last source of data collection was the semi-structured expert interviews. However, it was not used to collect results in order to respond directly to any RQ. The decision to run post-experiment expert interviews was made after the experiment. The reason was to collect input regarding a continuation of the project as there was interest in both sides (*Utrecht University*, *Bartiméus* school). Thus, the results that emerged through the expert interviews are used mainly for Future Research.

The expert interviews were conducted with two participants from the experiment that were skillful in games and game development and were eager to giver their opinion on *BongoBeats: Tap with me* and in possible next steps of the project from their point of view. These participants were Participant 2, a 28 years old (blind) volunteer from *Bartiméus* school who plays a lot of games in his free time, and participant 15, a 17 years old (blind) pupil, who is also considered a gamer and he is able to develop games on his own. The interview with participant 2 held on a voice call in Whatsapp, and with participant 15 on a voice call in Element (Matrix) platform. The interviews were recorded and were transcribed through the Otter.ai website. Then the transcription merged with the noted that were made thrugh the interviews were analyzed in the Word software.

7 Results

In this section, the Results are presented for each Research Question (Teams Score, game performance, Teams Collaboration, Game Experience), but also for the expert interviews that are used for the Future Research section of this thesis.

7.1 Teams score

The descriptive statistics for the RQ1: *Which teams did score higher in BongoBeats: Tap with me; an inclusive multiplayer rhythm game, the blind teams (two blind players), the Low-Vision teams (two players with Low-Vision) or the mixed teams (one blind, one LV player)?* Details on the descriptive statistics' values can be found on the Table 5. Two teams were consisted from two Blind (B) participants, two from two participants with Low-Vision (LV), and two were mixed teams (one Blind and one LV participant). The mean was 78.5 points, the median 67.5 points, the minimum 21 points, and the maximum 165 points. The total possible score for a team was 300 points. The blind teams are presented with blue colour in the bar chart (Figure 2), the Low-Vision (LV) teams with grey, and the mixed ones with orange. Taken into consideration the high value of the standard variation (51.77), the data set is spread out over a wide range of values. Considering the value of skewness (0.9), which is between 0.5 and 1, it is arisen the conclusion that the data set is moderately skewed.

Finally, there is no value in mode, as there were no teams that scored the same amount of points.

The different groups categories (blinds, LV, and mixed teams) were compared using the single factor ANOVA testing. The reason that there was not conducted ANCOVA, despite the intention to include two confound variables (teams prior social ties and gaming experience) is the small sample size. The average score for the blind teams was 105 points, for the LV was 36 points, and for the mixed were 94.5 points. Unfortunately, the results are not significant as the p value was 0.45. More details can be found in Table 6.

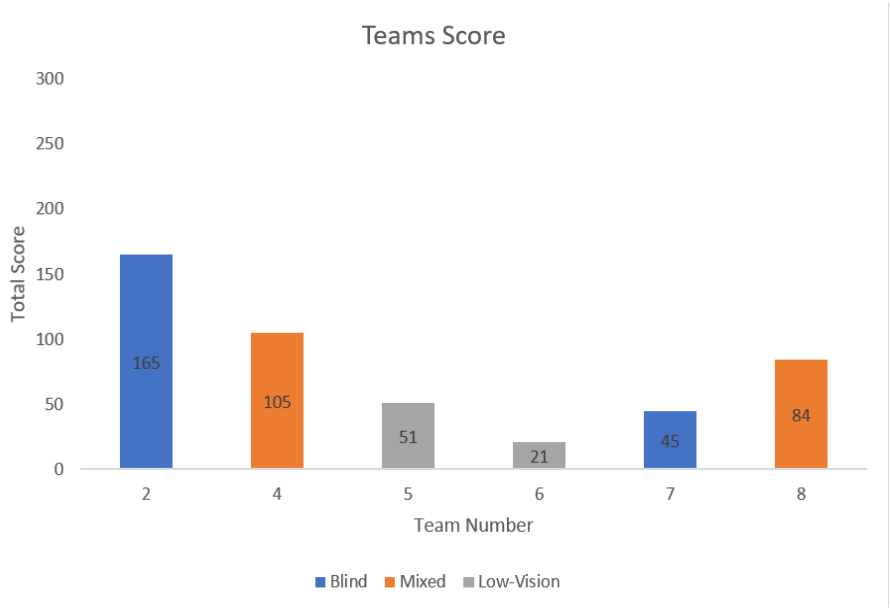

Figure 2: A bar chart with the total score of the teams.

Score	
Mean	78.5
Standard Error	21.13409567
Median	67.5
Mode	#N/A
Standard Deviation	51.76775058
Sample Variance	2679.9
Kurtosis	0.49874215
Skewness	0.902793469
Range	144
Minimum	21
Maximum	165
Sum	471
Count	6
Largest(1)	165
Smallest(1)	21

Table 5: A table which represents the descriptive statistics of RQ1 results.

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Blind	2	210	105	7200
Mixed	2	189	94.5	220.5
Low-Vision	2	72	36	450

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5529	2	2764.5	1.053745	0.450164	9.552094
Within Groups	7870.5	3	2623.5			
Total	13399.5	5				

Table 6: A table which represents the single factor ANOVA testing for RQ1.

Table 7: A table with the thematic analysis of RQ1.1 (game performance) Results.

Themes	Observers	Times Mentioned	Positive Comments	Negative Comments	Neutral Comments	Sessions	Times Mentioned	Positive Comments	Negative Comments	Neutral Comments
Feedback	3	3	1	1	1	1	1	0	1	0
Score	1	1	0	0	1	1	1	0	1	0
Performance	2	5	2	2	1	1	1	0	1	0

7.2 Game performance

For the RQ1.1, which concerns the game performance of the participants, a thematic analysis was conducted. The thematic analysis, which can be found in Table 7, presents the most frequent themes that were discussed in the interviews, the amount of interview sessions in which the theme was discussed, along with the total times that the theme was discussed in any interview, and the amount of the positive, the negative, and the neutral comments made on that theme by the interviewees. Then, there are visible the amount of observers that mentioned the themes, along with the total times that was mentioned by any observer, and the amount of the positive, the negative, and the neutral comments made on that theme by the observers.

The thematic analysis was conducted in MAXQDA software. The first step was to identify the most frequent themes by running search text queries. Three themes emerged that were mentioned through at least two interview sessions/observers. Then, it was found the amount of the positive, negative, and neutral comments that were made on a theme. The three themes from the least to the most frequent by the observers and the interviewees were Score, Performance, and Feedback. More details on the themes can be found through the corresponding subsections below. Also, all the details on the themes can be found in the Table 8.

7.2.1 Score

Starting with the least frequent theme, *Score*, one observer mentioned it one time through a neutral comment. The comment was the following:
Observer 4: "One pupil really wanted to know "How much did we score"?) – hence they really want to do it well and want to get feedback."
Furthermore, it was mentioned in one session one time negatively. The comment was the following:
Participant 12 (Session 7): "I don't know the score so no reason for extra motivation."
Some comments were applied to more than one theme. This happened as the themes in each thematic analysis were similar.

7.2.2 Performance

The *Performance* theme was mentioned by two observers, five times in total. Two comments on the theme were positive, two were negative, and one was neutral. The positive comments were the following
Observer 3: "Several people questioned about the timing of giving their partner the sign of left/right. I think they were motivated to perform well in the game."
Observer 2: "Participant 2 was very eager to perform." The negative comments were the following
Observer 3: "I feel some participants were eager to get better performance, but they failed because there weren't enough hints on whether the player receiving vibration or the player hitting keyboard being too late. I recall one participant even asked the reason of their poor performance."
Observer 2: "Some players mentioned they were uncertain about their performance, due to lack of feedback." The neutral comment was the following: When participant 15 played his second round with Anne, they didn't do well at the beginning, and when there's finally a correct hit (feedback from audio effect), he cheered with some words like "nice!".

7.2.3 Feedback

Finally, regarding the Feedback theme, three observers mentioned it and the same was the amount of the total times that was mentioned. One comment on the theme was positive, one negative, and one neutral. The positive comment was the following:
Observer 4: "One pupil really wanted to know "How much did we score"?) – hence they really want to do it well and want to get feedback."
The negative comment was the following:
Observer 2: "Some players mentioned they were uncertain about their performance, due to lack of feedback." The negative comment was the following:
Observer 3: "When participant 15 played his second round with participant 16, they did not do well at the beginning, and when there's finally a correct hit (feedback from audio effect), he cheered with some words like "nice!"."
Moreover, the theme was mentioned in just one interview session, one time through a negative comment. The comment was the following:
Participant 15 (Session 2): "It was unclear if the per- former was early or late. Feedback is missing in this regard. Good/bad was unclear."
The *Feedback* theme was the most frequently mentioned theme by the observers and the interviewees combined.

Table 8: A table with the Themes and Quotes from Observers and Interviewees from Thematic Analysis of RQ1.1 (game performance) Results.

Themes	**Observers**	**Interviewees**
Performance	Observer 3: "I feel some participants were eager to get better performance, but they failed because there weren't enough hints on whether the player receiving vibration or the player hitting keyboard being too late. I recall one participant even asked the reason of their poor performance." Observer 3: "When participant 15 played his second round with Anne, they didn't do well at the beginning, and when there's finally a correct hit (feedback from audio effect), he cheered with some words like "nice!"." Observer 3: "Several people questioned about the timing of giving their partner the sign of left/right. I think they were motivated to perform well in the game." Observer 2: "Participant 2 was very eager to perform." Observer 2: "Some players mentioned they were uncertain about their performance, due to lack of feedback."	Participant 16 (Session 2): "I felt that I was slow to respond while I was performing."
Feedback	Observer 3: See 2nd comment above (Performance) Observer 2: See 5th comment above (Performance) Observer 4: See comment below (Score)	Participant 15 (Session 2: "It was unclear if the performer was early or late. Feedback is missing in this regard. Good/bad was unclear."
Score	Observer 4: "One pupil really wanted to know "How much did we score"?) – hence they really want to do it well and want to get feedback."	Participant 12 (Session 7): "I don't know the score so no reason for extra motivation."

Table 9: A table with the thematic analysis of RQ2 (teams collaboration) Results.

Themes	Observers	Times Mentioned	Positive Comments	Negative Comments	Neutral Comments	Sessions	Times Mentioned	Positive Comments	Negative Comments	Neutral Comments
Vibrations	1	2	0	2	0	3	4	0	3	1
Keyboard	3	4	1	2	1	4	4	1	2	1
Controllers	2	2	0	0	2	5	5	1	1	3
Information Exchange	3	3	2	0	1	7	7	3	2	2
Dialogue Management	1	1	1	0	0	7	7	6	1	0
Motivation	3	5	4	1	0	7	11	6	1	4

7.3 Teams collaboration

The RQ's 2 results were analyzed through two means; a thematic analysis and a rating of the collaboration dimensions based on Meier's rating scheme [39]. The thematic analysis was conducted with the same way and steps as in RQ1.1. Hence, six themes emerged, that were mentioned through at least four interview sessions/observers. Then, it was found the amount of positive, negative, and neutral comments that were made on each theme. The six themes from the least to the most frequent by the observers and interviewees were the following: Vibrations, Controllers, Keyboard, Dialogue management, Information Exchange, and Motivation. More details can be found in the Table 9. The comments on the most frequent themes in regards to the teams collaboration can be found in Table 10.

The Figure 3 (bar chart) shows the average that participants scored in the game collaboration dimensions. As it is shown in the Figure 3 the participants scored (on percentage) from the lowest to the highest as following: Information Pooling = 84%, Time Management = 84%, Dialogue Management = 87%, Reciprocal Interaction = 88%, Technical. Coordination = 89%, Task Division = 92%, Mutual Understanding = 92%, Reaching Consesus = 93$ and Individual Task Orientation = 94%. The reason that the average percentages were used instead of the average scores, is the complexity of the scale which is measured from a -2 to a +2. Thus, if the average scores would be used instead of the average percentages it would not be so obvious that the participants scored very high in all the dimensions.

More details on the themes can be found through the corresponding subsections below. Also, all the details on the themes can be found in the Table 10.

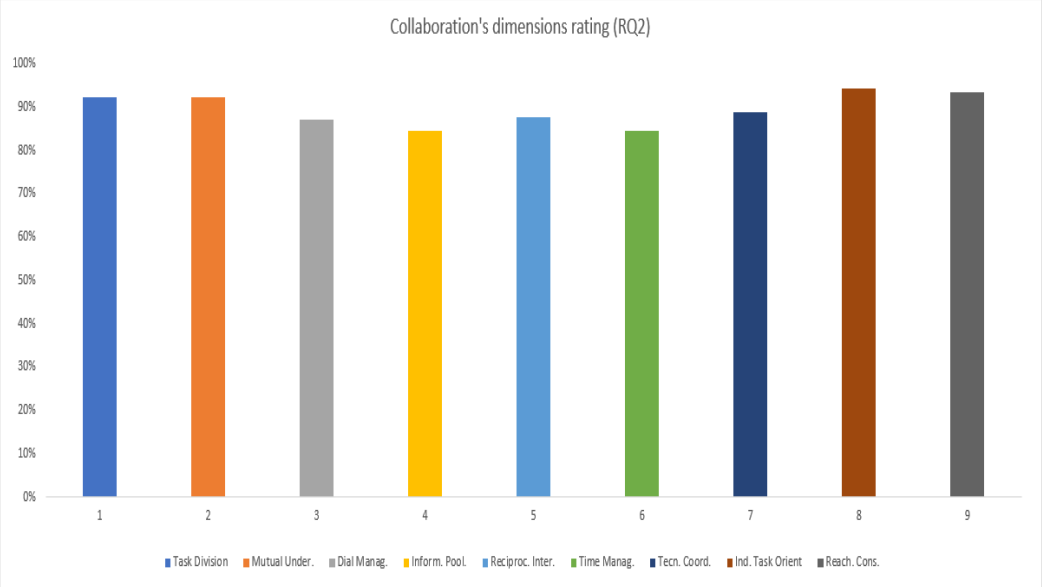

Figure 3: A bar chart with the average percentage score of the participants in the nine collaboration dimensions introduced by Meier [39].

7.3.1 Vibrations

Starting with the least frequent theme, *Vibrations*, one observer mentioned it two times both with negative comments. The comments were the following:
Observer 3: "I feel participants in general had a very low correctness rate on hitting the notes. Do people need more reaction time when feeling vibration on both sides?" (in contrast with participant 15 input through expert interview).
Observer 3: See 1st comment in Performance (Table 8) Session 3: "Vibrations not very noticeable, but not false; Suggested two vibration motors from an Xbox controller.
Also, it was mentioned in three interview sessions, four times in total, three times negatively and one through a neutral comment. The negative comments were the following:
Session 3: Vibrations not very noticeable, but not the fault; Suggested two vibration motors from an Xbox controller.
Participant 11 (Session 7): The controller in terms of vibration only around the round was too little, the whole controller vibrating would be better.
Participant 11 (Session 7): "The controller in terms of vibration only around the round was too little, the whole controller vibrating would be better." The neutral comment was the following: Participant 16 (Session 1): Rhythm of vibrations would be as a suggestion.

7.3.2 Controllers

Controllers theme was mentioned by two observers, two times, both through neutral comments. The comments were the following

Observer 2: “Multiple players mentioned to be willing to play this at home with friends, suggestions ranging from a mobile game with controller input to (most optimal) Switch.
Observer 3: “Several participants had difficulty with finding the left/right arrow key on the keyboard (so Henk sometimes helped them by putting their hand at the right place). It might be better if we support some other input devices with more identifiable keys (such as a mouse, or an Xbox controller).” It was also mentioned through five interview sessions five times, one through positive comments, one through a negative comments, and three through a neutral. The positive comment was the following:
Session 6: “The controllers went fine.” The negative comment was the following: Participant 1 (Session 1): Difficult at first with the controllers. The neutral comments were the following:
Participant 11 (Session 7): The controller in terms of vibration only around the round was too little, the whole controller vibrating would be better.
Session 3: Vibrations not very noticeable, but not the fault; Suggested two vibration motors from an xbox controller.
Session 5: One controller didn't work, but this was fixed, other couldn't help.

7.3.3 Keyboard

The *Keyboard* theme was mentioned by three observers, four times in total, one positively, two negatively and one through a neutral comment. The positive comment was the following:
Observer 2: “Participant 2 stated having experience with the controls.”
The negative comments were the following:
Observer 3: “Several participants had difficulty with finding the left/right arrow key on the keyboard (so Henk sometimes helped them by putting their hand at the right place). It might be better if we support some other input devices with more identifiable keys (such as a mouse, or an Xbox controller).”
Observer 2: “The keyboard input sometimes was uncomfort- able to use due to the heat, or arrows being too close to each other.” The neutral comment was the following:
Observer 1: “Pupils with LV were testing the arrows keys using their sight before they wore the facemask and start the game as performers.” *Keyboard* theme was mentioned also through four interview sessions, four times in total, one by a positive comment, two by negative comments and one by a neutral one. The positive comment was the following: Session 1: ”There were no issues with the keyboard.”
The negative comments were the following:
”Arrow keys were too close together, so sometimes misclick due to spasm in fingers”
Participant 7 (Session 6): “The keyboard was hot, so not pleasant.”
The neutral comment was the following:
Participant 16 (Session 2): ”Using the keyboard to create the illusion that pressing harder is better, through an example where pressing harder produced a different sound.”

7.3.4 Dialogue management

Regarding the *Dialogue management* theme, one observer mentioned it one time positively. The comment was the following:
Observer 2:“Participant 15 showed a lot of enthusiasm, also initiated some ideas on changing the communication (high/low pitched noises instead of left/right.”

Dialogue management was also mentioned in seven interview sessions, seven times, six with a positive comments and one with a neutral one. Some of the positive comments were the following:
Session 2: "No need to make long sentences, so the dialogue management was efficient." (similar comment in session 1)
Season 5: "No other dialogue, but efficient." The negative comment was the following:
Participant 1 (Session 1): "I didn't know what to say with both notes (left right at the same time)."

7.3.5 Information exchange

Concerning the *Information exchange* theme, three observers mentioned it, three times, two on a positive way and one on a neutral one. An example of a positive comment is the following:
Observer 4: "My impression was that there was a very collaborative spirit, but this is of course a very subjective feeling from my side."
The negative comment was the following:
Observer 3: "Several people questioned about the timing of giving their partner the sign of left/right. I think they were motivated to perform well in the game."
Information exchange was mentioned seven times in seven interview sessions, three positively, two negatively, and two with a neutral comment. An example of a positive comment on *Information exchange* theme in an interview session is the following:
Session 5: "Information exchange went perfectly."
An example of a negative comment is the following:
Session 6: "The music was too loud, so not all the information arrived."
An example of a neutral comment is the following:
Participant 2 (Session 1): "When I was the guide this went well, but when I was the performer, not all necessary information arrived."

7.3.6 Motivation

Finally, the *Motivation* theme, which was the most frequent, was mentioned from three observers, five times in total, four positively and one negatively, and eleven times in all the seven interview sessions. In the interview sessions the *Motivation* theme was mentioned six times positively, one negatively and four with neutral comments. An example of a positive comment from the observers is the following:
Observer 1: "Participant 2 stayed at the experiment classroom, almost for the whole experiment (he was very interested in the game)."
The negative comment was the following:
Observer 1: "The pupils who didn't like the song weren't so motivated to play the game."
An example of a positive comment from an interviewee is the following:
Session 2: "To be better than the other player, and to do well with each other."
The negative comment by an interviewee was the following: "The music had ruined me, took away concentration."
An example of a neutral comment by an interviewee is the following:
Participant 16 (Session 2): "The music was fun and acts as a motivator; but if you hear it four times it can get boring." It is important to note that as there was not space in the table six out of the eleven comments on *Motivation* theme was added on the table.

Table 10: A table with the Themes and Quotes from Observers and Interviewees from Thematic Analysis of RQ2 (teams collaboration) Results.

Themes	Observers	Interviewees
Dialogue Management	Observer 2:"Participant 15 showed a lot of enthusiasm, also initiated some ideas on changing the communication (high/low pitched noises instead of left/right)."	Session 1: "Understanding each other was fine." Session 6: "Not always because of the volume. Dialogue as such was efficient." Session 2: "No need to make long sentences, so was efficient." (similar comment in session 1) Season 5: "No other dialogue, but efficient." Session 1: "Reflection short input and dialogue was efficient." Participant 1 (Session 1): "I didn't know what to say with both notes (left & right at the same time)."
Information Exchange	Observer 2: See comment above (Dialogue Management) Observer 4: "My impression was that there was a very collaborative spirit, but this is of course a very subjective feeling from my side." Observer 3: See 3rd comment in Performance (Table 8)	Participant 1 (Session 1): See quote above (Dialogue Management) Participant 2 (Session 1): "When I was the guide this went well, but when I was the performer, not all necessary information arrived." Session 4: "Information exchange went smoothly." Session 5: "Information exchange went perfectly." Session 6: "The music was too loud, so not all the information arrived." Participant 12 (Session 7): Sometimes left right, left, was said; occasionally ambiguity in terms of expectation." Session 2: "All information was passed on"
Controllers	Observer 2: "Multiple players mentioned to be willing to play this at home with friends, suggestions ranging from a mobile game with controller input to (most optimal) Switch." Observer 3: See comment above (Keyboard)	Participant 1 (Session 1): Difficult at first with the controllers. Session 3: Vibrations not very noticeable, but not the fault; Suggested two vibration motors from an xbox controller. Session 5: One controller didn't work, but this was fixed, other couldn't help. Session 6: "The controllers went fine." Participant 11 (Session 7): The controller in terms of vibration only around the round was too little, the whole controller vibrating would be better.
Keyboard	Observer 3: "Several participants had difficulty with finding the left/right arrow key on the keyboard (so Henk sometimes helped them by putting their hand at the right place). It might be better if we support some other input devices with more identifiable keys (such as a mouse, or an Xbox controller)." Observer 1: "Pupils with LV were testing the arrows keys using their sight before they wore the facemask and start the game as performers." Observer 2: "The keyboard input sometimes was uncomfortable to use due to the heat, or arrows being too close to each other." Observer 2: "Participant 2 stated having experience with the controls."	Session 1: "Keyboard no issues" Participant 16 (Session 2): "Using the keyboard to create the illusion that pressing harder is better, through an example where pressing harder produced a different sound." Participant 4 (Session 3): "Arrow keys were too close together, so sometimes misclick due to spasm in fingers" Participant 7 (Session 6): "The keyboard was hot, so not pleasant."
Motivation	Observer 3: See 3rd comment in Performance (Table 8) Observer 2: See 4th comment in Performance (Table 8) Observer 1: "The pupils who didn't like the song weren't so motivated to play the game "Participant 15 was asking me if the game could be uploaded in the internet (e.g. in itch.io) so that he will be able to play it again." Observer 1: "Participant 2 stayed at the experiment classroom, almost for the whole experiment (he was very interested in the game)."	Session 2: "To be better than the other player, and to do well with each other." Participant 16 (Session 2): "The music was fun and acts as a motivator; but if you hear it four times it can get boring." Session 5: "The music had ruined me, took away concentration." Participant 4 (Session 3): "In the future I would play *BongoBeats: Tap with me* also with friends together in the call (I think skype/discord etc.)." Participant 2 (Session 1): "When I can game I forget about the world; it's a hobby." Participant 11, Participant 13 (Session 7): "Motivation was there because it was nice variety."
Vibrations	Observer 3: "I feel participants in general had a very low correctness rate on hitting the notes. Do people need more reaction time when feeling vibration on both sides?" (in contrast with Participant 15 input through expert interview). Observer 3: See 1st comment in Performance (Table 8) Session 3: "Vibrations not very noticeable, but not false; Suggested two vibration motors from an Xbox controller."	Participant 16 (Session 1): Rhythm of vibrations would be as a suggestion Session 3: Vibrations not very noticeable, but not the fault; Suggested two vibration motors from an Xbox controller. Participant 11 (Session 7): The controller in terms of vibration only around the round was too little, the whole controller vibrating would be better. Participant 11 (Session 7): "The controller in terms of vibration only around the round was too little, the whole controller vibrating would be better."

Table 11: A table with the thematic analysis of RQ3 (game experience) Results
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Themes	Observers	Times Mentioned	Positive Comments	Negative Comments	Neutral Comments	Sessions	Times Mentioned	Positive Comments	Negative Comments	Neutral Comments
Mood	1	1	1	0	0	7	7	4	1	2
Song	1	2	1	1	0	1	2	0	1	1
Music	2	3	2	1	0	7	19	5	10	4
Immersion	2	2	2	0	0	7	9	4	4	1
Competition	1	1	1	0	0	1	2	2	0	0
Friends	2	2	2	0	0	1	1	1	0	0

7.4 Game experience

The RQ's 3 results were analyzed also by a thematic analysis, and by rating the game experience dimensions based on GEQ [52] and PENS questionnaires [58] that are presented in the Methodology section.

The thematic analysis was conducted with the same way and steps as RQ1.1 and RQ2. Thus, six themes emerged that were mentioned through at least two interview sessions/observers. These were from the least to the most frequent the following: Competition, Friends, Song, Mood, Immersion, and Music. More details can be found in the Table 11.

The comments on the most frequent themes concerning the game experience of the participants can be found in Table 12. For example, in regards to the Friends theme, Observer 1 asked participant 2 if he would play *BongoBeats: Tap With Me* with sighted friends and he replied: "Of course, because I would like to challenge them. On the other hand, participant 4, a 13 years old blind pupil mentioned through his interview: "In the future I would play *BongoBeats* with friends together while having a call (in Skype/Discord, etc.)."

The rating of the Game experience PENS and GEQ dimensions is shown in Figure 4 (bar chart). From the lowest to the maximum, participants scored as following: Autonomy = 1.1, Immersion = 2.1, Competence = 2.6, Positive Affect = 2.8, Flow = 2.9, and Presence = 3.2.

More details on the themes can be found through the corresponding subsections below. Also, all the details on the themes can be found in the Table 12.

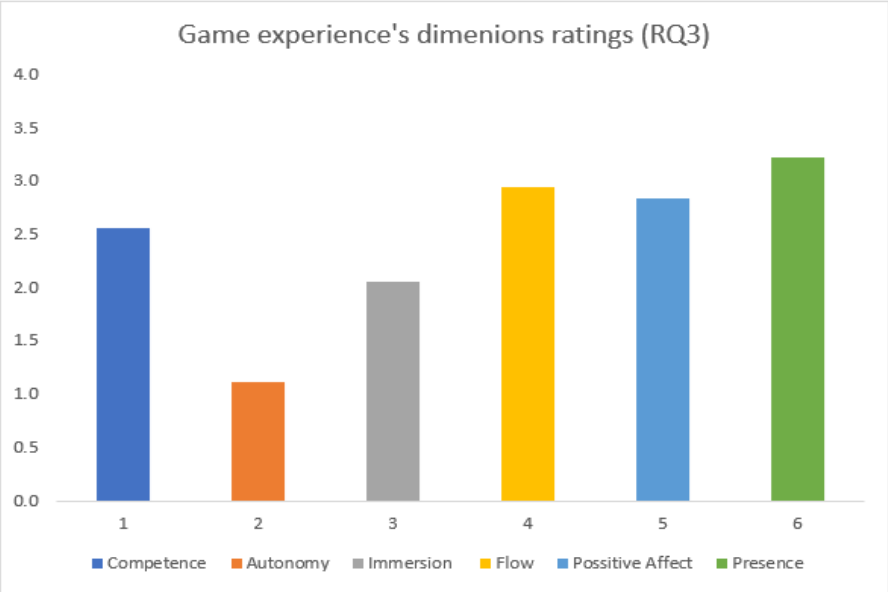

Figure 4: A bar chart with the average score of the participants in the six game experience (GEQ [34] and PENS [58] questionnaires) dimensions.

7.4.1 Competition

Starting with the least frequent theme *Competition*, one observer mentioned it one time, positively. The comment was the following: Observer 1: "When I asked participant 2 if he would play the game with sighted friends he told me of course, because he would like to challenge them." Also, it was mentioned in one interview session two times, both through a positive comment. An example of a positive comment was the following: Session 2: "To be better than the other player, and to do well with each other."

7.4.2 Friends

Continuing with the theme *Friends*, two observers mentioned it two times in total, both through a positive comment. An example of a comment is the following: Observer 2: "Multiple players mentioned to be willing to play this at home with friends, suggestions ranging from a mobile game with controller input to (most optimal) Switch." Moreover, it was mentioned in one interview session one time, with a positive comment. The comment was the following:
Participant 4 (Session 3): "In the future I would play *BongoBeats: Tap with me* also with friends together in the call (I think skype/discord etc.)."

7.4.3 Song

Two observer mentioned two times the theme, *Song*, one with a positive comment and one with a negative. The positive comment was the following:

Observer 1: “Participant 15 asked me the name of the song and the artist to listen to it to his phone and when I found it for him, he played it immediately.”
The negative comment was the following:
Observer 1: ”The pupils who didn’t like the song weren’t so motivated to play the game.”

7.4.4 Mood

The *Mood* theme was mentioned one time by one oobserver on a positive way. The comment was the following:
Observer 4: “There was a lot of joy and excitement in the room to participate in the experiment “For the sake of science, yes please blindfold me”.
This strengthens the idea on future co-creation with them.” It was also mentioned seven times in the seven interview sessions, four times positively, one negatively and two in a neutral way. An example of a positive comment is the following:
Session 1: “Just the music made it better, so definitely positive. It definitely made you feel good.”
An example of a negative comment is the following:
Session 6: ”I don’t feel better after playing; It worked mostly as a distraction.”
The neutral comment was the following:
Session 5: Yes a little bit, music was too loud, and therefore not feeling much better.”

7.4.5 Immersion

Two observers mentioned two times the *Immersion* thee, both on a positive note. An example of a comment is the following:
Observer 1: “Participant 15 was seemed that he was immersed to the game as he was moving his head to the beat and every time, he was misclicking he was shouting.”
Furthermore, it was mentioned in all the seven interview sessions, nine times in total, with four positive, four negative and one neutral comments. An example of positive comment is the following:
Participant 2 (Session 1): ”I was very immersed. ”Game mode” turned on.”
An example of a negative comment was the following:
Session 2: ”Due to interaction/social aspect less immersiveness; less visual so less feeling of being in the game world.”
The neutral comment was the following: Session 5: ”I was not really immersed.”

Due to space limitations, five out of the nine comments on the *Immersion* theme were added on the Table 12.

7.4.6 Music

The most frequent mentioned theme was *Music*. Two observers mentioned it three times, two with a positive comments and one with a negative one. Also, it was mentioned nineteen times in the seven interview sessions. An example of a positive comment by the observers is the following:
Observer 2: “Participant 14/Participant 15/Participant 16 were really fond of the music. Participant 15 also showed this by moving his head with the beat.”
The negative comment by the observer was the following:
Observer 2: “Some participants stated that the music was too loud.” On the other side, an example of a positive comment by an interviewee is the following:

Session 7: "I was focused on the rhythm of the music."
An example of a negative comment from an interviewee is the following:
Session 7: Music was a little too loud, and occasionally I was pressing arrow keys by mistake."
Finally, an example of a neutral comment made by an interviewee is the following:
Session 4: "Music was getting a little annoying. Own choice in music style would be more fun."

Due to space limitations, four out of the nineteen comments on *Music* were added on Table 12.

Table 12: A table with the Themes and Quotes from Observers and Interviewees from Thematic Analysis of RQ3 (game experience) Results.

Themes	Observers	Interviewees
Music	Observer 1: "There was a music classroom in the school in which children spend lots of hours per day Observer 2: "Participant 14/Participant 15/Participant 16 were really fond of the music. Participant 15 also showed this by moving his head with the beat." Observer 2: "Some participants stated that the music was too loud."	Session 4: "Music was getting a little annoying. Own choice in music style would be more fun." Session 7: "I was focused on the rhythm of the music." Session 7: Music was a little too loud, and occasionally I was pressing arrow keys by mistake Session 5: Yes a little bit, music was too loud, and therefore not feeling much better."
Mood	Observer 4: "There was a lot of joy and excitement in the room to participate in the experiment "For the sake of science, yes please blindfold me". This strengthens the idea on future co-creation with them."	Session 1: "Just the music made it better, so definitely positive. It definitely made you feel good." Participant 15 (Session 2): "Well cheerful through, through music; through cooperation and being busy." Session 4: "No positive influence (I certainly wouldn't want to play this every day)", Participant 4 (Session 3): "Like that Evangelos is so happy, nice that involvement is there, that gives a positive feeling." Session 3 "Nice change from the day's entertainment at school so definitely feeling better." Session 6: I don't feel better after playing; It worked mostly as a distraction."
Immersion	Observer 1: "Participant 15 was seemed that he was immersed to the game as he was moving his head to the beat and every time, he was misclicking he was shouting." Observer 2: "Not all players were similarly immersed into the game. Mostly visible within the players (not sure of all names, but participant 15. for sure, Participant 3 from team 3 and possibly for the last Team (participant 10/participant 11) that were shouting/cursing when they would missclick." Participant 2: "Very much, Game mode turned on."	Participant 15 (Session 2): "Due to interaction/social aspect less immersiveness; less visual so less feeling of being in the game world." Participant 2(Session 1): "I was very immersed. "Game mode" turned on." Session 4: No immersiveness experienced." Session 5: "I was not really immersed." Participant 7 (Session 6): "Very easily distracted and not paying much attention."
Friends	Observer 1: "When I asked participant 2 if he would play the game with sighted friends he told me of course, because he would like to challenge them." Observer 2: See 1st comment in Controllers (Table 12)	Participant 4 (Session 3): "In the future I would play *BongoBeats: Tap with me* also with friends together in the call (I think skype/discord etc.)."
Competition	Observer 1: See comment above (Friends)	Session 2: "To be better than the other player, and to do well with each other."
Song	Observer 1: See 2nd comment in Motivation (Table 10) Observer 1: "Participant 15 asked me the name of the song and the artist to listen to it to his phone and when I found it for him, he played it immediately." Observer 1: "The pupils who didn't like the song weren't so motivated to play the game."	Participant 8 (Session 6): "I think it was an ugly song."

7.5 Expert interviews

The results from the two expert interviews were analyzed by conducting a thematic analysis. However, this thematic analysis, was not conducted in MAXQDA, but through the Word software. Search text queries were run to find the most important themes that were discussed in the interviews. The importance comes from the frequency of a theme that was mentioned by the two interviewees. Along with each theme, it is presented in Table 13, the category it belongs, from whom it was mentioned, and a quote from the interviewee(s) on that theme. The most important/frequent themes, along with their categories were Game for VI people (category): Interests (theme), Games for VI people: VI (game) community, BongoBeats: Collaboration, BongoBeats: Music, BongoBeats: Singe player, BongoBeats: Vibrations, Future: Sighted Friends, Future: H/W (Nintendo Switch), Future: Feedback, Future: Accessibility, Future: Inclusivity, and Future: Classical Music. For the six out of the twelve themes, more details are given through the corresponding subsections below. Details about all the themes can be found below in the Table 13.

Table 13: A table with the thematic analysis of Expert interviews Results.

Categories	**Themes**	**Mentioned by**	**Quotes**
Games for VI people	Interests	Both	Participant 2: "I play a bit of everything. For example, sports (NFL, racing) RPGs (Warcraft) and Pokémon." Participant 15:: "I play Spelunky 2 (alone and with a sighted friend), and Lumines (if there is a way to make it accessible, it will be amazing)."
Games for VI people	VI (game) community	Both	Participant 2: "I have met most of my friends through gaming. There is a sort of VI game community with several levels." Participant 15:: "Blind community is happy about anything you give to it."
BongoBeats	Collaboration	Participant 2	Participant 2: "I enjoyed the collaborative gameplay and is rather unique."
BongoBeats	Music	Participant 15	Participant 15: "I really liked the musical elements of the game that are aligned with beatsaber, and guitar hero."
BongoBeats	Singe player	Both	Participant 2: "I would like to have the opportunity to play alone. I mostly don't have people around me, in which I can cope cooperatively play."
BongoBeats	Pace	Participant 15	Participant 15: "It was a slow game."
BongoBeats	Vibrations	Participant 2	Participant 2: "It was good to feel the long and the different direction's vibrations."
Future	Sighted Friends	Both	Participant 2: "I would like to challenge all of my sighted friends in *BongoBeats: Tap with me*" Participant 15 (suggestion): "You can make the game competitive between VI and sighted children. Find a way to tell the user to have the same input, practice on their world and then fight between each other." Participant 15: "I play *Spelunky 2*, together with a sighted friend who helps me during the game. We also play against each-other."
Future	H/W (Nintendo Switch)	Both	Participant 2: "Nintendo Switch platform extension, to don't exclude sight community" Participant 15: "Almost every child has Nintendo switch"
Future	Feedback	Participant 15	Participant 15: "Give feedback for everything. Explain to the user what is happening. For example, add dynamic feedback to indicate how close/far the player was from hitting the notes."
Future	Accessibility	Both (contradictory opinions)	Participant 15: "Accessibility is the next big thing." Participant 2: "Accessibility is not popular anymore." Participant 15: "Think about how the game will be fair to every category (blinds, low-vision, and sighted). Adapt every feature (for example, the speed of the game)."
Future	Inclusivity	Participant 2	Participant 2: "Inclusivity is getting more popularity day by day, but still its new so there's a gap. Well done for jumping there already."
Future	Classical Music	Both	Participant 2: "I think that classical music does introduce a new game element in the game." Participant 15: "Classical music (baroque, Bach, Handel) music so complex that you can hear it thousand times and not get bored."
Future	Contribution	Both	Participant 2: "Learnt from various angle that I am the game master. Love to contribute, Love to land a hand to developments by saying out land my opinion on game features and characteristics." Participant 15: "I can help with game development if you share the project in GitHub."

7.5.1 VI (game) community

Regarding the *VI (game) community* theme, both participant 2 and participant 15 gave information through their expert interview. While the latter gave more general information regarding the interest of the VI community, the former revealed that he belongs in a VI game community. The comment that reveals that information is the following: "I have met most of my friends through gaming. There is a sort of VI game community with several levels." The general comment that participant 15 made about the VI community is the following:
Participant 15: "Blind community is happy about anything you give to it."

7.5.2 Sighted Friends

The initial goal of this thesis was to offer the ability to VI children to play with all of their friends even if they are sighted. Unfortunately, this could not happen as any "mainstream" school responded to invitation to test the game there. Thus, expert interviews were used to ask two participants that showed big interest in *BongoBeats: Tap with me* if they would play it with sighted friends. They both responded positively, and their response is very promising. More specifically, participant 2 mentioned: "I would like to challenge all of my sighted friends in *BongoBeats: Tap with me*." Participant 15 was giving suggestion on how to make the game fair between sighted and non-sighted players. He mentioned the following: "You can make the game competitive between VI and sighted children. Find a way to tell the user to have the same input, practice on their world and then fight between each other."

7.5.3 Nintendo Switch

Both participants talked about *Nintendo Switch*, and the value it can give to *BongoBeats: Tap with me* in the future. More specifically, participant 2 mentioned the following:
Participant 2: "Nintendo Switch platform extension, to don't exclude sight community"
Along the same lines, participant 15 mentioned the following: "Almost every child has Nintendo switch."

7.5.4 Accessibility

Concerning *Accessibility* the opinions of the participants were contradictory. Participant 2 believes that inclusivity is the new trend in games leaving behind accessibility, by mentioning the following:
Participant 2: "Accessibility is not popular anymore."
In contrast, participant 15 believes that accessibility in games is something new that just came to stay, as he mentioned:
Participant 2: "Accessibility is the next big thing."

7.5.5 Inclusivity

Participant 2 was talking a lot about inclusivity in games, as something new and very promising. More specifically, he mentioned: "Inclusivity is getting more popularity day by day, but still its new so there's a gap. Well done for jumping there already."

7.5.6 Classical Music

Both participants talked about classical music and what it can offer to *BongoBeats: Tap with me* in the future. Participant 2 mentioned the following: "I think that classical music does introduce a new game element in the game." On the same page, Participant 15 mentioned the following: "Classical music (baroque, Bach, Handel) music so complex that you can hear it thousand times and not get bored."

8 Discussion

In the discussion section, first the experimental setup changes that had to been made are explained. Then, for every research question, the results are explained and contextualized in the theoretical framework of the thesis. After that, the limitations of this thesis are given which are mainly due to the necessary experimental shift focus. Finally, the future research subsection is presented, which is divided into two parts; the continuation of the thesis project and the testing with both VI and sighted children.

8.1 Experimental setup changes

The initial targeted environment to test *BongoBeats: Tap with me*, was a school with both sighted, partially sighted, and non-sighted pupils. The reasons for this choice are explained in the problem statement section. Unfortunately, despite that an invitation, along with the experiment summary was sent to a plenty of "mainstream" schools, through Annemiek van Leendert, any of those responded. Thus, an alternative had to be chosen. This was to test the game in *Bartiméus* school, a special school with VI pupils, with which there is already a connection with *Utrecht University* as Tycho, and Lisa tested *BongoBeats* [67] there. *Bartiméus* school responded immediately to the invitation.

Hence, three major changes had to been made to the experimental setup. The first was that instead of dividing the teams between sighted, non-sighted, and mixed, the distinction was based on the degree of the visual impairment. Thus, there were three categories of teams; the blind teams, the Low-Vision (LV) teams, and the mixed teams (one Blind and one pupil with Low-Vision).

Moreover, as the sample was much smaller than expected, because there was only one school to test the game, the research questions had to been changed from quantitative to qualitative. With that small sample size, the results from quantitative data could not be generalized. However, RQ1, which measured the teams score, a discrete and quantitative variable, did not change, but a qualitative sub research question was added to the quantitative research question, as complementary. The sub research question (RQ1.1) is the following:
How did the Visually Impaired (VI) children perform in BongoBeats: Tap with me; an inclusive multiplayer rhythm game?
The RQ2 was changed from:
Which teams collaborate more successfully in an inclusive multiplayer rhythm game, VI, mixed , or sighted teams?
to:
How did the Visually Impaired (VI) children collaborate in an inclusive multiplayer rhythm game?
As for the RQ3, it was changed from:
Is the gaming experience equal for VI and sighted children in an inclusive multiplayer rhythm game?
to:
How did the Visually Impaired (VI) children experience BongoBeats: Tap with me; an inclusive multiplayer rhythm game?

The third change was also a result of the large reduce on the experimental sample. As the experimental sample was small, there was no meaning for including confound variables. Therefore, there were no sub research questions about the impact of the prior social ties and the background gaming experience on the teams collaboration,

as it was initially planned. In previous research, it has been found, that experienced players dominate discussion within the team, especially if they are friends with their teammates [10]. Hence, it seems that not only background gaming experience and prior social ties have impact on teams collaboration, but also, that there is an interaction effect, between background gaming experience and prior social ties. However, the mentioned effects could not be investigated in this thesis, due to the small sample size.

In the limitations section, it is explained how the necessary change on the experimental setup limited the thesis.

8.2 Teams score

Due to the small sample size of the participants, there were no significant results in teams score. Hence, it cannot be concluded if blind, LV, or mixed teams have advantage in an inclusive multiplayer rhythm computer game.

However, the high value of the standard variation shows that the data set is spread out in a wide range. This can be understood also by the high difference between the minimum (21 points) and the maximum (165 points) teams score. From these two indicators, but also by looking that bar chart in Figure 2, it can be concluded that teams scored quite differently. That can be due to quite of variables, such as the impairment degree (Blind vs LV), the background gaming experience, the prior social ties, or something else. Unfortunately, as the sample size was small, this thesis could not confirm [10]'s results in regards to the impact of background gaming experience, and prior social ties on the teams score in a multiplayer game. Moreover, it could not be tested the effect of the visual impairment degree to the team's score, as it was planned.

8.3 Game performance

A very common comment both from observers and interviewees mentioned concerning game performance, was that the lack of the feedback had an impact on it. For example, observer 2 obtained the following conclusion: "Some players mentioned they were uncertain about their performance, due to lack of feedback." A comment from which can be understood what kind of feedback was missing is the following:
Participant 15 (Session 2): "Unclear if the performer was early or late. Feedback is missing in this regard. Good/bad was unclear." From that comment, it can be understood that on the one hand, it was not always clear to participants if the tries of the performer to hit the notes were successful or not. On the other hand, it was not clear whether the performer had to be faster or slower, and how much faster/slower.

Regarding the first issue, it seems that the audio feedback was not that discrete (distinctive), especially when a note was mishit (only drum sound). Some good game examples that utilized discrete audio feedback are *Em Busca do Santo Grau* [47] and Ninja Cactus [13, 14]. Moreover, it might be a good idea to combine the drum sound, with a shattered glass sound when a note is mishit, such as in *BongoBeats* [67]. With that change, the audio feedback would probably be more discrete, and thus, the chance of misunderstanding during the game due to audio feedback would be reduced.

Concerning the second issue, it would be helpful if the audio feedback would be different depending on how far the performer was from hitting a note successfully. A solution could be to use high-pitched sound if the note was far away when the performer tried to hit it, and low-pitched sound if the performer was close to hit it.

Another comment that was mentioned frequently was that the participants wanted to know the score. For example, participant 12 mentioned in interview session 7: "I don't know the score so no reason for extra motivation." On the same page was observer 4 as she mentioned: "One pupil really wanted to know "How much did we score"?) – hence they really want to do it well and want to get feedback." Hence, it seems that the existence of an audio scoreboard is important for VI players performance. Initially, it was planned to use a scoreboard, as the game mechanics framework of [68] had been taken into consideration. Unfortunately, a scoreboard was not added to the game due to time limitations in the last phase of the game development. From the feedback of the interviewees and the observers, it seems that a scoreboard is necessary for an inclusive rhythm multiplayer game for VI pupils, such as *BongoBeats: Tap with me*. Examples of games for VI players that utilize 3D audio scoreboard are Ninja Cactus [13, 14], and Em Busca do Santo Grau [47].

Finally, the participants perceived differently their performance. Participant 16 mentioned in the interview session 2 the following: "I felt that I was slow to respond while I was performing." In contrast, participant 15 mentioned in his expert interview the following: "It was a slow game." That might be due to plenty of reasons, such as the different gaming background gaming experience, and the different familiarity degree with laptops' keyboard. As players performed differently, it is suggested for a future game on this topic, to provide to the players a variety of gaming levels to choose from.

8.4 Teams collaboration

By looking the average (percentage) score of the participants in the nine collaboration dimensions of Meier [39] at Figure 3, it is concluded that the teams collaborated very well in general. The least average (percentage) scores which were in Information Pooling = 84%, and Time Management = 84%, were still high. The dimensions in which the participants scored the highest on average were Reaching Consesus = 93%, and Individual Task Orientation = 94%. That means that on the one hand, participants were agreeing very easily during the game (reaching consesus), and on the other hand, they were highly motivated (Individual Task Orientation).

The latter, can be observed also by looking the quotes derived by the thematic analysis of the results from RQ2 which are visible in table 10. For example, observer 1 mentioned the following: "Participant 15 was asking me if the game could be uploaded in the internet (e.g. in itch.io) so that he will be able to play it again." It was clear both from both the observers and the interviewees that the latter were highly motivated when they played, but also most of them, wanted to play *BongoBeats: Tap with me* again. Participant 4 mentioned in interview session 3 the following: "In the future I would play *BongoBeats: Tap with me* also with friends together in the call (I think skype/discord etc.)."

An important conclusion that can be obtained from both the average (percentage) score of participants in collaborative dimensions, but also from the comments of the interviewees and the observers, is that the teams were very good at exchanging information and at managing the dialogue during their game rounds. The corresponding average (percentage) score was 84% (information pooling dimension) and 87% (dialogue management dimension). In parallel, in Session 5, it was mentioned the following: "Information exchange went perfectly." Furthermore, regarding the *Dialogue management* theme, it was mentioned in Session 2 the following: "No need to make long sentences, so the dialogue management was efficient." However, this was not al-

ways the case, and a few participants had some issues with the dialogue management. For example, participant 1 mentioned in the interview session 1 the following: “I didn’t know what to say with both notes (left right at the same time).”

8.5 Game experience

By looking at Figure 4, the bar chart which presents the average score of the participants in the six GEQ [34] and PENS [58] game experience dimensions, it is observed that the participants scored the highest in positive affect = 2.8 (out of 4), flow = 2.9 (out of 4), and presence = 3.2 (out of 4). In all these three game experience dimensions, participants scored on average percentage at least 70%.

Flow is similar with immersion and presence, but measures different things. While flow is related to the focus on the game objectives [52], presence concerns a deeper level of concentration, to the game world [58]. Immersion goes even beyond concentration, and is related with the absorption of the players in the game world [52]. The difference between presence can be derived through the following comment:
Participant 15 (Session 2): ”There were no distractions, so could be present, only this sense of immersiveness is missing.” It seems from that comment, but also, from the bar chart (figure 4) that not all players were immersed (immersion = 2.1 out of 4). Moreover, the comments of the participants on *immersion* were contradictory. Some of the players were really immersed. A such example, is participant 2 who mentioned in the interview session 1 the following: ”I was very immersed. ”Game mode” turned on.” The others weren’t immersed at all. A such example comes through the interview session 4. There, it was mentioned the following: ”No immersiveness experienced.”

As for autonomy, it was expected a low score (average score = 1.1 out of 4) due to the collaborative nature of the game. The question that participants were asked to indicate their autonomy was the following:
How independent do you think you were during the game? Do you think you were free to make your own decisions?
A typical answer in that question comes from session 2: ”Follow-up was needed for the other player, so little autonomy.” *BongoBeats: Tap with me* is a multiplayer game and players have to help each-other continuously, since their tasks are co-dependant. Hence, it is logical to observe little autonomy.

Finally, there were some interesting comments regarding the *Music* and the *Song* themes. In session 4 it was mentioned the following: “Music was getting a little annoying. Own choice in music style would be more fun.” Observer 1 was on the same page, as he mentioned: ”The pupils who didn’t like the song weren’t so motivated to play the game.” From these two comments it can be concluded, that participants would like to have the ability to select between multiple songs and genres in order to enjoy the game. That might be difficult in terms of game development, as the notes in *BongoBeats: Tap wih me* were synchronized manually with the correct timing of the beat, and thus, this task took time. However, in [40] an approach for beat tracking with MIR algorithms is suggested. With that approach, the notes will be synchronized automatically with the beat of a song, and hence, it would be feasible to add plenty of songs and genres to a rhythm game, even if there will be time restrictions in the phase of the game development.

8.6 Limitations

There are four main limitations in this thesis. First, the game was not tested with both sighted and non-sighted pupils. Second, despite there were visuals in the game, all the participants in the experiment played with the audio-haptics setup, and hence, the visuals of the game were not tested. Another important limitation was the small sample size (sixteen participants in total). Finally, from the sixteen participants, one of them is not a pupil in the school, but a 28-years old (blind) volunteer.

Regarding the first limitation, which was the lack of sighted participants in the experiment, there was a complementary source for data collection, the expert interviews. Through the expert interviews, the perception of two VI participants from the experiment was collected regarding the potentiality to play *BongoBeats: Tap with me* with sighted friends in the future. They both were positive and that is a promising finding. However, any "mainstream" school responded to the invitation for running the experiment there, and thus, there are not experiment's results on the collaboration and the game equality between sighted and non-sighted players. One of the initial goals of this thesis was to monitor the collaboration between sighted and non-sighted players and to observe if an inclusive multiplayer rhythm computer game which provides audio-visual cues to sighted and audio-haptics cues to non-sighted players is equal and fair for both categories. Despite that most of the VI pupils, at least in the Netherlands, go to "mainstream" school, it is derived from this thesis, that it is not easy to reach these school for testing a (game) experiment there. Though, it is important to test an inclusive multiplayer serious game for VI children with sighted children as well. The reason is the need of the VI children to share experiences with their sighted peers in order to be understood and come closer to them. It has been found through the literature review, that it is common for VI children to face discrimination or/and marginalization in "mainstream" schools due to their impairment [56, 50, 59, 55].

As for the visuals of the game, despite that they were present in the game, they were not used in the experiment. The participants with Low-Vision were asked when they had the guide role, if they prefer to receive haptics or visual informational cues regarding the notes' direction and timing. They all chose the haptics cues, which were vibrations through the two HTC Vive Pro controllers. Hence, it could not be tested if the players with the audio-visual setup compared to the players with the audio-haptics setup perform similarly. Also, the findings from [70, 46] regarding the importance of haptics cues to boost VI players' performance could not been supported or rejected. However, the sample size was small, and thus, it was impossible to reach significant results from the quantitative data. So, even if some players played with the audio-visual setup and the others with the audio-haptics setup, conclusions could not be obtained in relation with the fairness of the game between the audio-visual and the audio-haptics setup.

The small sample size was a limitation, as significant results could not be occured. The RQ1 was in regards to the teams score and the intention for it was to compare the blind, the LV, and the mixed teams score. Unfortunately, due to the sample size not only, significant results did not occur, but also, the confound variables *(prior social ties of the players*, and *background gaming experience*) were not included. Hence, this thesis could not support or reject [10]'s results about the effect of the prior social ties and the gaming experience of the players on the game performance.

Last, one out of the sixteen participants is not a pupil in *Bartiméus* school, but a 28 years old (blind) volunteer. This is a limitation, as *BongoBeats: Tap with me* is focused mainly on (VI) children. However, it is a minor issue, as the input of that

participant was very useful and helpful as he showed a big interest in the game and he was eager to contribute more. Besides, he considers himself as a regular gamer. Therefore, he was one of the two participants that were chosen for the expert interviews and he provided his feedback also regarding the next steps of this thesis project, and a possible extended version of *BongoBeats: Tap with me*. As he mentioned in his expert interview: "Learnt from various angle that I am the game master. Love to contribute, Love to land a hand to developments by saying out land my opinion on game features and characteristics."

8.7 Future research

In this section first it is explained how and why this thesis project should be continued. Then, the need for further research to test an inclusive rhythm multiplayer computer game with sighted children as well, is presented.

8.7.1 Continuation of the thesis project

Dynamics of Youth research pillar of *Utrecht University* and *Bartiméus* school showed a big interest in this thesis project. Thus, two paths emerged for the continuation of it. On the one hand, more researches and theses can touch upon this thesis and extend on this topic. The first step has been achieved already. Marc Ferriggi a colleague from UU, has just started his thesis on the topic of inclusive music serious games for VI children. On the other hand, funds can be collected by the *Dynamics of Youth* research pillar of *Utrecht University* in order to create commercial games for the VI children, possibly by co-creation with *Bartiméus* school. The following comment from the observer 1 shows the need for a commercial version of *BongoBeats: Tap with me*. "Participant 15 was asking me if the game could be uploaded in the internet (e.g. in itch.io) so that he will be able to play it again." Along those lines, participant 4 mentioned during the interview session 3 the following: "In the future I would play *BongoBeats: Tap with me* also with friends together in the call (I think skype/discord etc.)." Additionally, two comments from the expert interviews make it clear why a co-creation of a commercial game with *Bartiméus* school is a good idea. Participant 2 during his expert interview mentioned the following: "Learnt from various angle that I am the game master. Love to contribute, Love to land a hand to developments by saying out land my opinion on game features and characteristics."
Participant 15 was on the same page, and he mentioned in his expert interview the following: "I can help with game development if you share the project in GitHub."

8.7.2 Testing with both VI and sighted children

In this thesis, the game could not be tested with sighted children, as it was planned. However, it is important in the future to test an inclusive rhythm multiplayer computer game with both VI and sighted children for three reasons. First, to offer the opportunity to VI pupils to share a playful experience with their sighted friends. Second, to monitor the collaboration between the VI and sighted children. Third, to observe if an inclusive rhythm multiplayer computer game designed mainly for VI players will be enjoyed also by the sighted players. Fourth, to test if an inclusive computer game such as BongoBeats: Tap with me; with two setup options: an audio-visual and an audio-haptics, can guarantee game fairness and equality between the VI and the sighted players.

On a positive note, it was observed through the expert interviews that participants are eager to play with and against their sighted friends. More specifically, participant 2 stated the following: "I would like to challenge all of my sighted friends in *BongoBeats: Tap with me*." Furthermore, participant 15 mentioned the following: "I play *Spelunky 2*, together with a sighted friend who helps me during the game. We also play against each-other."

9 Conclusion

The aim of this thesis was to create an inclusive multiplayer rhythm computer game for VI children to shed light on their performance, collaboration, and experience. Hence the research questions were the following:
[RQ1:]Which teams did score higher in BongoBeats; Tap with me; an inclusive multiplayer rhythm game, the blind teams (two blind players), the Low-Vision teams (two players with Low-Vision) or the mixed teams (one blind, one LV player)?
[RQ1.1:] How did the Visually Impaired (VI) children perform in BongoBeats; Tap with me; an inclusive multiplayer rhythm game?
[RQ2:] How did the Visually Impaired (VI) children collaborate in BongoBeats: Tap with me; an inclusive multiplayer rhythm game?
[RQ3:] How did the Visually Impaired (VI) children experience BongoBeats: Tap with me; an inclusive multiplayer rhythm game?

The game was developed in Unity and was an extension of *BongoBeats* [67] which was inspired from the famous VR rhythm game *Beat Saber* [8]. It was played in teams of two, with two roles; the guide and the performer. While an electro-swing was playing in the background, the game objective was to hit the notes that were coming towards two bongo beats with drum sticks. The guide was holding two HTC Vive Pro controllers to receive vibrations when a note was coming toward the left, the right or both bongo drums. Her task was to inform the performer, who was handling the drumsticks with the arrow keys of the laptop, to hit the notes at the right timing. The game was tested in *Bartiméus* school; a special school for VI pupils. Fifteen VI participants from 10 to 17 years old (plus one participant 28 years old) played the game. Four of them were excluded from the results of RQ1 (teams score). Two of them excluded, because a technical issue occured in one of their teams game rounds and the game stopped suddenly. The other two excluded, since their teammate was playing for a second time, as they previously played the game with another team. For the other research questions, all sixteen's participants input was used.

Regarding, the RQ1 (teams score), quantitative data were collected through the Unity software. Blind teams scored 105 points on average, LV scored 36 points, and mixed teams scored 94.5 points. The minimum teams score was 21 points and the maximum teams score was 165 points. The mean was 78.5 points. Despite that an ANOVA test was run, the results were not significant as the p value was 0.45. This was expected due to the small sample size (12 participants, 6 teams). As for the other three research questions RQ1.1 (game performance), RQ2 (teams collaboration), and RQ3 (game experience) qualitative data were collected through two methodologies; interviews with all sixteen participants, and observation. Moreover, for RQ2 (teams collaboration), the rating scheme of Meier [39] for assessing collaboration was used. Hence, participants were rated on nine collaboration dimensions based on their answers through the interviews. Similarly, for RQ3 (game experience) participants were rated based on their answers on six game experience dimensions taken by highly utilized

game experience questionnaires (the GEQ [34], and the PENS [58]).

Regarding their performance, participants and observers mentioned frequently the following themes (from the least to the most frequently mentioned): Score, Performance, Feedback. The most common comment in regards to the teams score was that there was a lack of feedback in *BongoBeats: Tap with me*. In regards to RQ2 (teams collaboration), participants scored very high in each collaboration dimension on average. The lowest average percentages were in Information Pooling = 84%, and Time Management = 84%, and the highest average percentages were in Mutual Understanding = 92% and in Reaching Consesus = 93%. In addition, the collaborative spirit of the participants was observed also by the observers. Participants and observers talked frequently (from the least to the most frequent) about the following themes in relation with the teams collaboration of the participants: Vibrations, Controllers, Keyboard, Dialogue management, Information Exchange, and Motivation. As for the RQ3 (game experience), participants scored from the lowest to the highest as following: Autonomy = 1.1, Immersion = 2.1, Competence = 2.6, Positive Affect = 2.8, Flow = 2.9, and Presence = 3.2. Moreover, participants and observers were stating comments for the following themes in relation with their game experience (from the least to the most frequently mentioned): Competition, Friends, Song, Mood, Immersion, and Music.

Despite the intention to test *BongoBeats: Tap with me* with sighted pupils as well, any "mainstream" school did respond to the experiment invitation. This caused a limitation for this thesis, as findings regarding the collaboration between sighted and non sighted players could not been derived. Additionally, all the players played with audio-haptics cues, and therefore, conclusions concerning the fairness of the game between an audio-visual and an audio-haptics setup could not been obtained. It is important in the future to test an inclusive multiplayer (rhythm) computer game for VI pupils with sighted pupils as well, in order to know if it is feasible for VI to play together with sighted peers, and if they will both enjoy it. The testing to only one school, had as a result another limitation; the small sample size. Last, some themes were supported by a 28 years old volunteer who participated in the study. *BongoBeats: Tap with me* was targeted mainly to VI pupils. However, the input of that participant was valuable, as he is a regular game, and has a large amount of gaming knowledge.

This thesis provides findings on game performance, collaboration and experience of VI pupils within an inclusive rhythm multiplayer computer game. Hence, it contributes on the topics of inclusive play and accessibility, and serious games for VI children. More specifically, it was found in this thesis that the VI players scored high in all nine collaboration dimensions of Meier [39]. In addition, almost three out of four participants stated that the game had a positive impact in their mood. On another note, there were differences in players performance; some players were faster than the others, in music liking; some people liked a lot the electro-swing song, some others found it annoying, and in motivation; some were focused and motivated while playing, some others were distracted and demotivated. Furthermore, a lot of the participants mentioned that there was a lack of informational (audio) feedback regarding the outcome of each try a performer made to hit a note. Therefore, it is recommended that an inclusive rhythm multiplayer computer game for VI children should have a variety in choices (music, levels, etc.) and provide more (audio) feedback.

On a positive note, this thesis proves through *BongoBeats: Tap with me*, that an inclusive multiplayer rhythm (computer) game for VI children empowers the collaborative spirit of VI children and brings them joy, at least to most of them. The latter is in line with the findings from [25] which concerns the prominence of a multiplayer function to improve VI players enjoyment. Almost three out of four participants en-

joyed *BongoBeats: Tap with me* and stated that it had a positive impact on their mood. It is likely that the reason that one out of four participants did not enjoy the game, was because she did not like the song. However, the music effect on players moods should be studied in future research, with more songs and genre choices within an inclusive rhythm multiplayer computer game for VI children. The sure thing is that the rhythm genre was a good choice for the VI audience. As participant 15 mentioned in his expert interview: "I really liked the musical elements of the game that are aligned with *Beat Saber*, and *Guitar Hero*." Besides, it is the predominant genre for the VI gaming audience [53].

Finally, the most important learning insights which were derived in this thesis and can be utilized for future research on inclusive multiplayer rhythm games for VI children are the following. First, plenty of discrete and detailed audio feedback is needed to help the VI children cope with the game. Second, to offer variety in songs/music genres and level of difficulty to satisfy the interests, preferences, and abilities of all the children. Last, there is a need for testing inclusive rhythm multiplayer games which are designed for VI children with sighted children as well, and thus, this thesis calls for the corresponding action. The reasons for that are to assist the VI children to be included in peers/friends groups at school and to test if an inclusive multiplayer rhythm computer game which is designed mainly for VI children can be also played and enjoyed by sighted children.

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10 Appendices

Figure 5: A picture from the experiment. Participant 2 on the left handles the arrow keys, as he is a performer, and Participant 1 (on the right) holds the controllers, as he is the guide.

Figure 6: A picture from the experiment. Participant 1 (in front) holds the HTC Vive Pro controllers as he is the guide and Participant 2 (behind) handle the arrow keys of the laptop keyboard as he is the performer.

Figure 7: A picture from the experiment. Participant 14 (on the left) handles the arrow keys, as he is a performer, and Participant 15 (on the right) holds the controllers, as he is the guide.