

Multiplayer Functionality In HRTF (Head-Related Transfer Function) Audio Games To Increase Players' Interest

Saad Ali

Uppsala University, saad.ali.5175@student.uu.se

Mainstream video games retain players' interest with dynamic updates of graphics such as game characters, levels, themes and other game inventory items. For visually impaired players, updates in graphics for player retention are not very efficient. Video games for people with serious visual impairment rely heavily on audio. The players are presented with either frequent audio instructions or 3D audio to be able to roughly judge the state of the game. In both cases, the players could either be overwhelmed by frequent audio instructions or might lose interest in the game after some time. A possible reason could be that there are limited ways to evolve these games to keep the players interested as compared to games developed for sighted players. Multiplayer functionality can potentially bring a continuous stream of challenges and competitive situations in games. The research question investigated in this thesis focuses on whether the addition of multiplayer functionality in 3D audio game will increase the level of player interest. The hypothesis was evaluated by performing an experiment. The results of the study showed that multiplayer functionality can significantly increase the level of player interest and enjoyment in 3D audio based game for people with serious visual impairment.

Additional Keywords and Phrases: Insert Hrtf games, Visually impaired, Audio Games, Multiplayer Accessible games, player Interest.

This work was submitted in partial fulfilment for a master's degree in Human-Computer Interaction at Uppsala University, Sweden, on 2022-06-17. Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author must be honoured. © 2022 Copyright is held by the owner/author(s).

1 INTRODUCTION

Playing games is an excellent source of entertainment. Video games in particular are very popular among young adults and the proportion of players is also growing in other age groups [1]. People with serious visual impairment who are unable to use graphical interfaces have very limited and restricted access to video games[2]. One of the potential reason of limited access is the usability of currently available video games. Secondly, video games make extensive use of 2D and 3D graphics to provide a playable and enjoyable experience. The majority of the mainstream video games rely heavily on graphical components and a lot of effort has been made in recent years to improve the visual and audio quality[3]. This development in aesthetics and audio has left only few games which are accessible to people with serious visual impairment. As developing a game can be very expensive and requires a huge market to make profit. The market of accessible games for visually impaired is very small as compared to the market of sighted players.

According to a survey done in 2015, there are around 36 million people with severe visual impairment worldwide including all age groups [4]. Hence, this is not a big enough market for video game developers to target. Although the development of accessible games for visually impaired is slow, there are, however, a fair amount of accessible games (both physical and digital) available for people with serious visual impairment to play. Existing video games developed for people with serious visual impairment depend greatly on sounds. In most of the audio games, the state of game is notified to players by playing audio instructions. Audio games are mostly based on audio instructions without any visuals and realistic physics in the game. Lack of graphics and realistic physics could potentially decrease the player interest and enjoyment. Furthermore frequently playing audio instructions can overwhelm the players and the player can end up just following the orders having no agency. To address these problems and to enhance the user experience, modern accessible video games for visually impaired people use HRTF (Head Related Transfer Function) audio. HRTF is a phenomenon that describes how an ear receives sound from a sound source. Through HRTF a listener can pinpoint the location of sound source. HRTF based games provide more agency to a player in the game. Through HRTF players can pinpoint different game objects (characters/obstacles etc.) in the game and can control the flow of game instead of just following the audio instructions. However, one potential problem with such games is that players might lose interest after some time. Should that indeed be a problem, a possible reason is that there are limited ways in which to evolve these games to keep the players interested as compared to games developed for sighted players. Video

games mostly retain the players' interest with frequent updates in graphics such as game characters, levels and other game inventory items. For visually impaired players, updates in graphics for player retention are not very efficient. For visually impaired players the experience of playing a game remains constant regardless of how realistic the graphics are. In addition to that, graphic updates do not bring new challenges in a game for players with severe visual impairment which are crucial for enjoyment. A continuous stream of challenges and competitive situations are regarded as a key element of enjoyment in games [5]. One research study [5] aimed at evaluating the hypothesis that players expect a game situation to be more enjoyable when confronted with competitive elements in the game. The results of the study show that competitive situations in game significantly increase the players enjoyment [5]. Online multiplayer games can potentially bring a continuous stream of challenges and competitive situations in games. Players can play with each other over the network and the popularity of online multiplayer games has increased rapidly. Increased popularity and technological advancement in social media platforms have introduced a new type of game genre known as Social Games, that is, games played on social media platforms such as 'Facebook' [19]. Social Games make use of asynchronous multiplayer functionality through which the players can play online with their friends. Social Gaming has experienced massive popularity and according to a survey done in 2012, Facebook alone had 235 million monthly active players[21]. Multiplayer functionality is regarded as one of the most important feature for engagement in casual games [21] hence, the hypothesis that this will be true also for audio-based games is unfounded. A common view regarding the increased popularity of multiplayer games is that they bring continuous stream of competitive situations in a game.

1.1 Research Question

The research question investigated in this thesis focuses on whether the addition of multiplayer functionality in an HRTF audio game will increase the level of player interest and is done by evaluating the following hypothesis by performing an experiment: *"The addition of multiplayer functionality in an HRTF audio game for visually impaired users will increase the level of player interest"*.

2 BACKGROUND

2.1 Defining Player Interest

Interest is defined as the feeling of being engaged, caught-up and curious [6]. Enjoyment is to feel pleased with or about one's engagement in an activity[6]. Player interest and enjoyment are related to each other as playing a game can initiate the feeling of enjoyment and decrease in enjoyment can lead to lower interest in that activity. This relationship between interest and enjoyment is rather more obvious in the case of video games because video games are an exceptional source of enjoyment/having fun. Experience of having fun is generated when a person feels interested and at the same time feels enjoyment[6]. Enjoyment can be further described using theoretical terms such as immersion, presence and flow. The term immersion is used to describe the feeling of engagement or the capacity of the game environment to create a feeling of being present in the game environment while retaining some awareness of the surrounding[7]. Presence is defined by the experience of being inside the virtual game environment and retaining the normal state of consciousness[7]. Flow or being in the state of flow is described as feeling enjoyment including the feeling of being in control and experiencing time distortions[7]. Theoretical terms such as immersion, presence and flow were argued to be an indicator of engagement and enjoyment in video-game playing [7,8]. Similarly, interest is also defined as a feeling of being engaged [6]. From the above discussion, it can be concluded that interest and enjoyment overlap each other. Furthermore, an increase in enjoyment could lead to a higher interest in an activity. Since the engagement and interest are defined using the theoretical terms like 'flow' and 'presence' indicating that the players experience time distortion when engaged in an enjoyable and interesting activity. In simple terms, it indicates that a person perceive that the time is passing faster than normal when engaged in enjoyable activities. This time distortion phenomenon inspired the methodological choice of using game-play time as a direct measure of player interest in a game version and questionnaire questions to measure the enjoyment and interest in game version.

2.2 Related Work

There are broadly two types of accessible games for people with serious visual impairment, physical and digital games. Physical games such as basketball, braille bingo-boards and braille dice etc. are made accessible with some alterations e.g. a basketball with sound, braille cards[9]. There are number of alteration aids available to make physical games accessible for visually impaired people. Many non-profit organizations make and sell such tools including braille stickers, chess boards, playing cards etc. Digital games are more popular nowadays and offer a diverse collection of games and are easily available for everyone to download as compared to physical games. There are very few digital accessible games for visually impaired people and prior to the year 2000, the only accessible games that one can find were developed by the Swedish library of talking books [10].

2.2.1 Audio Games

Computer games designed for visually impaired people rely heavily on audio. There is a variety of audio games available on the internet for people with visual impairment. Audio-based games are completely based on audio instructions without graphics. The most famous game in this category is the racing game “Top Speed 3 – Racing in the dark”. Top speed 3 is completely based on audio without any graphics. The game includes many sound effects such as car engine, brakes, collisions etc. and audio instruction to help users control the vehicle in the game [11]. Furthermore it offers multiple racing tracks and a wide range of sound effects to enhance the gameplay experience. It also offers an online multiplayer version of the game that supports up to seven players. However, the development is discontinued and multiplayer functionality is no longer available.

Top speed 3 is an interesting game but there are some problems. Firstly, frequent audio instructions in gameplay can overwhelm the player and the player end up just following the announcements rather than racing. Secondly, such types of games have no graphics which means there is no actual physics in gameplay. Graphics are still important even though the players cannot see them. Without the use of graphics, players might think that they are just following the orders and not actually controlling the game. In addition to that, players might want to share their progress with others or get help from sighted users in understanding the game.

Above mentioned issues with the audio games such as lack of graphics and realistic physics suggests that the graphics are an important part of game, regardless if the players are sighted or visually impaired. So the game build for this experiment make use of graphics to address this issue.

2.2.2 Audio Visual Games

Audio-visual games feature both audio and visuals where the visual elements of the game are simplified to a very basic level e.g. instead of controlling the avatar in a virtual 3D world, a 2d grid is used to represent the game world. “Super Egg Hunt” is an audio-visual game for people with visual impairment in which players can move the avatar on a grid to locate objects only from audio feedback [10]. Super Egg Hunt uses stereo sound and variations in volume and pitch of sound for easy and pleasant handling of gameplay [10]. Since the market for accessible games is very small and less profitable, developers are driving their focus to inclusive games. The philosophy of inclusive design is aimed to include as many people as possible and especially the people who are excluded by swiftly changing technology [12]. There are number of inclusive audio-visual games available online which are accessible to people with visual impairment. Not all games are aimed toward people with severe visual impairment or blindness. Many of the games feature high contrast colours, magnified text, menus and speech recognition to help people with mild visual impairment. The most impressive inclusive audio-visual game title developed for people with severe visual impairment is “The Last of Us 2”, an action-adventure game developed by Naughty Dog [13]. The game is rated 9.5/10 by the players with visual impairment[14]. The game features a complex storyline with action and 60 assistive settings to make the gameplay highly accessible for people with visual impairment. The problem however is that there is a steep learning curve and is targeted toward the people who have a strong passion for games. Furthermore, most audio-visual games offer very simplified gameplay with very few updates. The player might lose interest after some time as the game fails to offer new challenges in the game, adding more features can complicate the gameplay and without innovation the game becomes boring.

The above mentioned issues with audio visual games such as highly simplified gameplay which can potentially decrease the player interest in game after some time of gameplay. On the other hand increasing the number of features in gameplay can complicate gameplay can potentially make the gameplay difficult to understand and play. These two issues require a solution which can increase the player interest and enjoyment without complicating the gameplay. The game build for this experiment therefore was kept simple in terms of gameplay features or functionalities. Furthermore multiplayer functionality was used to bring a continuous stream of challenges in the gameplay to make the gameplay experience more enjoyable and interesting without complicating the gameplay.

2.2.3 HRTF Games

HRTF (head-related transfer function) is a phenomenon that describes how an ear receives sound from a sound source point in space. As the sounds travel from space and reaches to the ear it is transformed by the shape and size of the head, ear canals and shape and size of oral cavities. Through HRTF listener can pinpoint the location of sound source. HRTF based games provide more agency to a player in the game as the player can pinpoint different game objects (characters/obstacles etc.) in the game and can control the flow of game.

An interesting example of HRTF audio-based game is “Racing Auditory Display (RAD)”. RAD is a 3D racing game with realistic graphics and physics just like any other 3D racing game [15]. RAD uses HRTF audio sonification technique through which the player can be made aware of the position of car and idea about the curves and turns of the racing track [15]. RAD is specifically focused on racing games and the main research is about finding the optimized values for HRTF audio slider to

improve the audio feedback system. HRTF slider calculates and provides a value to adjust the volume of sound for the left and right ears so that players can effectively judge the position of the car and race track turns and curves.

The focus of previous research and development on HRTF games is mostly on two aspects: (1) focus on improving the technology itself with new tools and techniques, (2) development of games to help people enhance their cognitive abilities and navigational skills. Games like "The audio doom game [16]", "Pyvox [16]" and "blindsides [16]" are such examples. In the audio doom game players are presented with a virtual environment with walls and corridors, players have to find the exit while avoiding monsters with the help of audio cues[16]. Seven visually impaired children played the game and the results of the study have shown improvement in their spatial cognitive skills[16]. Other games "Pyvox" and blind-side are based on similar gameplay and purpose.

HRTF based games provide more agency to a player in gameplay as the player can pinpoint different game objects (characters/obstacles etc.) in the game and can control the flow of game. However, one of the problems with such games is that players lose interest after some time. This is because there are very few ways to evolve these games to keep the players' interest as compared to games developed for sighted players.

HRTF audio games provide a much more pleasant experience than simple audio games by providing audio cues instead of frequent audio instructions. The game designed for experiment therefore make use of HRTF audio instead of simple audio instructions.

2.2.4 Multiplayer Games

Online multiplayer games can potentially bring a continuous stream of challenges and competitive situations in games. Players can play with each other over the network and the popularity of online multiplayer games has increased rapidly [21]. According to statistics 64% of young adults in United states are gamers and 65% of those gamers play online multiplayer games [20]. According to a survey done in 2017 in Australia 67% of Australian individuals play games regularly and 92% of those individuals play online multiplayer games [20].

A common view regarding the increased popularity of multiplayer games is that they bring continuous stream of competitive situations in a game. Currently available multiplayer games for people with severe visual impairments are very few and most of the games are discontinued. Currently, the most famous developer of such games is RSGames.org. Over 20 games including multiplayer games were developed by RSGames which are completely accessible to people with severe visual impairment[17]. The games developed by RSGames are audio games without any visuals and HRTF audio. It is unclear if any online multiplayer game with HRTF audio exists.

3 METHODOLOGY

The type of research undertaken in this research study is primarily quantitative. However, a small portion of qualitative data was also gathered and analyzed. The primary aim of this research study is to evaluate the following hypothesis:

"Addition of multiplayer functionality in HRTF audio games for visually impaired users will increase the level of player interest".

The overarching methodology of this research study was experimental that is the hypothesis was evaluated by performing an experiment. Both quantitative and qualitative data were collected and analyzed. Quantitative data was used to evaluate the hypothesis whereas qualitative data was analyzed to get further insights and understanding of participants' experiences and/or to form a new hypothesis.

3.1 Implementation

To evaluate the hypothesis an HRTF-audio based game was developed with two versions. The first version of the game was without multiplayer functionality and the second version was with multiplayer functionality. The reason for implementing the game from scratch was simply because it was unclear if any specific game was available to use. The game was developed in Unity3d game engine and c# programming language. Photon Unity Networking Engine APIs were used to implement the multiplayer functionality in the game.

Due to the limited amount of time a simple 2D endless runner themed game was developed. The game contained HRTF-audio, graphics and simple audio for interaction with menu options in the game. Graphics were added so that the users can share their achievements and gameplay with other sighted users.

3.2 Sample

In total 14 participants were recruited using a convenience sampling method to play both versions of the game and to fill out the survey. The participants within the age group of 18 - 30 years old were recruited because this demographic was easily accessible for this research study. Participants were recruited online and a brief introduction to this research study was given.

3.3 Survey

An online survey was conducted with all the participants. Each participant filled out the questionnaire twice i.e after playing the first version of the game and then after the second version. However, the two open-ended questions of the questionnaire could only be answered by participants once they have played both versions of the game. Therefore, those two questions were sent to participants after they had played both versions of the game. Carrying out the questionnaire twice was needed to compare the participants' level of interest between the two versions of the game.

3.4 Gameplay Time

Along with the questionnaire, game-play time was also collected for both versions of the game. Game-play time is the total amount of playtime in seconds recorded by the game application. Game-play time was used as a main dependent variable as longer game-play time indicates higher level of interest in game version.

3.5 Questionnaire

The questionnaire contains both Likert scale questions and open-ended questions to measure the players' interest between the two versions of the game. In total, the questionnaire consists of 15 questions. The first question in the questionnaire was about participants' age. The second section of the questionnaire consists of 12 questions about the participants' interest in the game. The third section consist of 2 open-ended questions where participants were asked to share why they think one version of the game is more interesting than the other.

The questions used in the questionnaire were selected from two existing research studies [1,2] aiming to measure the engagement and enjoyment in video game-playing respectively. In both of these research studies [1,2] theoretical terms such as immersion, presence and flow were argued to be an indicator of engagement and enjoyment in video game-playing [1,2]. Engagement is an indicator of interest. Interest is defined as the feeling of being engaged, caught-up and curious [3]. Interest also contributes to intrinsic motivation by the initiation of attention and exploratory behaviour [4]. Questions regarding challenge, reward, accomplishment and desire to make progress in game were used to measure the players' interest as they relate to the feeling of being curious and engagement. Both research studies [1,2] also contained questions for measuring the usability of the game application and some other questions about the specific theme of the game. Questions regarding usability and game theme were excluded as they were not relevant for this research study.

The two qualitative questions were included to firstly investigate why the participants think one version of the game is more interesting and enjoyable than the other version. Although the two questions were very similar but were investigating two different theoretical terms 'Interest' and 'Enjoyment'. Secondly, these questions were added to investigate whether the participants perceive each term differently or regard 'interest' and 'enjoyment' as similar concepts.

3.6 Procedure

Participants were divided into two groups (Group-A and Group B) with an equal number of participants in each group. The first group (Group A) was asked to play the single-player version of the game for 7 days and then the multiplayer version of the game for another 7 days. The second group (Group B) was asked to start with the multiplayer version of the game and then after 7 days switch to the single-player version of the game. As it could happen that experience from one version of the game may affect the experience of other version of the game, therefore, participants were divided into two groups, each group starting with a different version of the game.

The distribution of the questionnaire and collection of game-play time was done after each 7 days period. All the participants were informed about the collection of gameplay time before the experiment. Participants were asked to share the log file generated by the game application which contained the game-play time in seconds. The questionnaire was created using Google forms and sent to all participants via email

Game-play time was used as a main dependent variable where "order-of-play" and "type-of-play" were used as independent variables. Order-of-play refers to the order in which the participant played both versions of the game that is first the single-player version and then the multiplayer version and vice versa. Type-of-play refers to the game version that is single-player and multi-player versions. From the questionnaire data, an overall score was calculated for each filled questionnaire. The overall score was used as a dependent variable and a higher score indicates a higher level of player interest in the game version.

To mimic the visually impaired users all the graphic components were hidden and the game screen was replaced with a black screen since all the selected participants were sighted users.

3.7 Data Analysis

3.7.1 Quantitative

The data from the survey was analyzed in two ways. Firstly, the game-play time was used as a main dependent variable where “order-of-play” and “type-of-play” were used as independent variables. Descriptive analysis was done to analyze the data. Furthermore, a test of statistical significance was done to measure the order effect.

From the questionnaire data, an overall score was calculated for each filled questionnaire. The overall score was calculated by the simple addition of the values of each selected option. Each option of the Likert scale questions was assigned a numeric value from 1 to 5. Positively worded questions were assigned with the following values (strongly-agree = 5, Agree=4, neutral =3, disagree = 2 and strongly-disagree = 1) where the values for negatively worded questions were opposite. Descriptive analysis and tests of statistical significance were done to analyze the data. The overall score was used as a dependent variable and the “type-of-play” was used as an independent variable having two categories (Single-player and multiplayer version).

3.7.2 Qualitative

Secondly, the qualitative data from the survey was analyzed using the content analysis method. According to satu et. al [1] content analysis method is used to analyze and interpret qualitative data and represents a systematic and objective means of describing and quantifying phenomena [1].

From the qualitative data, relevant findings were highlighted by making brief notes. The data was then coded to identify themes and patterns. Finally, conclusions were drawn from the data. Qualitative data was also helpful in understanding and reasoning the results from quantitative analysis.

3.8 Survey Questions

3.8.1 Basic Questions

- Please State your Age.

3.8.2 Player Interest Questions

- I felt like I lost track of time while playing.
- I did not feel like I wanted to keep playing.
- I played longer than I meant to.
- I can't tell that I'm getting tired
- Time seems to kind of standstill or stop.
- I lose track of where I am.
- I really get into the game
- I was focused on the game.
- I felt that this game provided an enjoyable challenge.
- I felt a sense of accomplishment from playing the game.
- I did not feel a desire to make progress in the game.
- I don't answer when someone talks to me.

3.8.3 Qualitative Questions

- Between the two versions of the game (single-player and multiplayer version), why do you think one version is more enjoyable than the other?
- Between the two versions of the game (single-player and multiplayer version), why do you think one version keeps your interest in the game to play more?

4 GAME DESIGN

In order to evaluate the hypothesis an HRTF-audio based game was developed with two versions (singlePlayer and Multiplayer version). Due to the limited time, the functionality of the game was kept simple. An endless runner style hyper-casual game was developed with 2D graphics.

After launching the game, players are presented with a menu screen as shown in figure 1 where players can either choose to play the singleplayer version or the multiplayer version. Furthermore, a simple tutorial is also implemented as shown in

figure 2 containing the instructions on how the game works and how to play the game. The game also records the scores and players can view the scores. Scores are simply the time in seconds the user has played the game. Since all the participants for this experiment were sighted players and usability is not the focus of this research study, therefore menu and instructions are text-based without any accessibility feature for visually impaired.

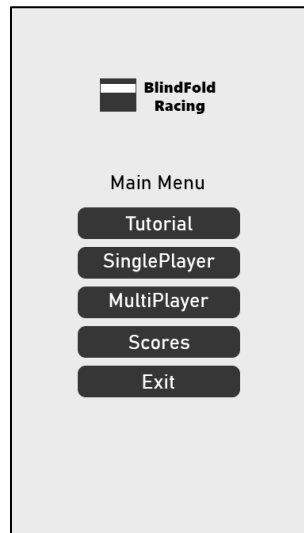


Figure 1: Menu Screen.

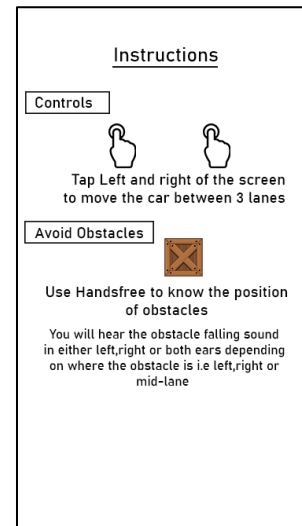


Figure 2: Instructions

The gameplay contains a racing car and three lanes as shown in figure 3. By tapping the left, and right of the screen players can move the car between the 3 lanes. The goal of the game is to avoid obstacles which randomly appears in the lanes (left, right and mid). To mimic the visually impaired players the screen of the gameplay was replaced with a black screen with the message "You are Blindfolded" as shown in figure 4. The virtual blindfold was enabled automatically by the game application upon starting the gameplay and was kept enabled throughout the gameplay. This is to ensure that players don't get any visual feedback either intentionally or non-intentionally.

HRTF audio functionality allows the player to know in which lane they are currently driving the car. If the car is in the left lane the players will hear the running engine sound in the left earphone. Similarly, if the car is in the right lane the player will hear the engine sound in the right earphone. If the car is in mid-lane the player will hear the sound in both left and right earphones. Similarly when an obstacle is generated a sound effect of a heavy object falling will be played in either left, right or both earphones depending on where the obstacle is generated that is left, right or mid-lane respectively.



Figure 3: Obstacles placed in 3 lanes.

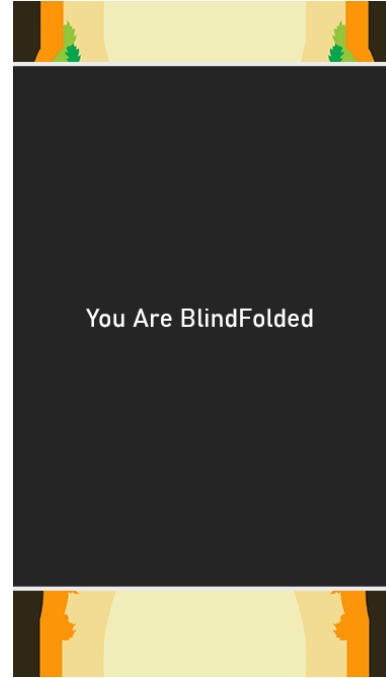


Figure 4: Blocked gameplay view.

In the Multiplayer version (as shown in figure 5) of the game two players can play together and whoever survives longer by dodging the obstacles wins the game.



Figure 5: TwoPlayer - Multiplayer Gameplay.

5 RESULTS

In total, 14 participants played the game and filled out the survey questionnaire. The participants were divided into two equal groups (Group A and Group B) with 7 participants in each group. Group A was asked to play the single-player version of the game for 7 days and then the multiplayer version. Group B was asked to start with the multiplayer version of the game and then switch to the single-player version. The questionnaire's distribution and game-play time collection were done after each 7 days period. A significance level of 5% (0.05) was used as a decision criterion throughout for all statistical testing.

The results are divided into three parts, first, the gameplay-time data was analyzed by checking the normality of data and also for any significant order effect, after that a test of statistical significance was done to test the main hypothesis with gameplay-time. Secondly, the questionnaire data were analyzed by checking the normality of data and any significant order effect induced by order of gameplay, after that a test of statistical significance was done to test the main hypothesis by questionnaire score data. Finally, the qualitative data were analyzed to provide further support or contradict the results of statistical tests.

5.1 Gameplay Time

Gameplay time was recorded in seconds to compare the level of interest between the single-player and multiplayer versions of the game. The average gameplay time of the single-player version of the game was 72 minutes, whereas, for the multiplayer version of the game, the average gameplay time was 84.71 minutes. (See Appendix 2 for playtime statistics).

5.1.1 Normality of Data

A test of normality (Shapiro Wilk test) was done to determine if the data are normally distributed or not. As can be seen in figure 6 below, no support is evident for the hypothesis that the data are non-normally distributed.

Normality Test (Shapiro-Wilk)				
			W	p
PlayTime-SinglePlayer	-	Playtime-Multiplayer	0.899	0.109
Note. A low p-value suggests a violation of the assumption of normality				

Figure 6: Shapiro Wilk test of normality.

5.1.2 Order Effect

First, a brief descriptive analysis was done as shown in figure 7 below. "Order Of Play" refers to the order in which participants played the game version that is STM (Single-player to Multiplayer) and MTS (Multiplayer to Single-player). In figure 7 below, it can be observed that the first group (STM) who started with the single-player version and then played the multiplayer version have a higher mean playtime for the single-player version which is 412 in seconds and 6.8 in minutes. However, the mean playtime in STM for the multiplayer version is lower than MTS which is 34 in seconds and 0.56 in minutes.

From the descriptive analysis, it can be observed that the difference between the two groups exists however a test of statistical significance was performed to check if the difference is statistically significant or not. The result of the between-group t-test as shown in figure 8 show that the difference between the two groups is not statistically significant. Hence, no evidence has been found suggesting that there is an order effect.

	OrderOfPlay	TypeOfPlay	PlayTime
Mean	STM	Single-Player	4526
		Multi-Player	5066
	MTS	Single-Player	4114
		Multi-Player	5100

Figure 7: Mean Playtime (in seconds) of Groups and game version.

Independent Samples T-Test				
		Statistic	df	p
playTime	Student's t	0.941	26.0	0.355

Figure 8: Independent samples T-Test Result.

5.1.3 Gameplay Time Between Two Versions

Gameplay time is the direct measure of player interest, higher playtime indicates a higher level of player interest whereas low playtime indicates that the level of interest is low. By performing the within-groups t-test, the results of the test indicate that there is indeed an effect, the mean playtime of the multiplayer version is significantly higher than the single-player version.

In figure 9 below it can be observed that the p-value of the t-test is <0.001 which is lower than the decision criterion (0.05). Thus, we can reject the null hypothesis (H0) which states that "there is no significant difference in playtime between the two versions of the game".

Paired Samples T-Test					
				statistic	p
PlayTime-SinglePlayer	Playtime-Multiplayer	Student's t		-7.19	< .001
				13.0	

Figure 9: Paired samples T-Test Result.

In figure 10 below it can be observed from the descriptives that the mean playtime of multiplayer is higher than the single-player version and as shown in figure 9 the difference is statistically significant. So the hypothesis that the multiplayer version is more interesting than the single-player version receives support.

Descriptives					
	N	Mean	Median	SD	SE
PlayTime-SinglePlayer	14	4320	4440	461	123.3
Playtime-Multiplayer	14	5083	5100	236	63.0

Figure 10: Mean PlayTime of game versions.

5.2 Questionnaire Data

Each participant has filled out the survey twice, one for the single-player and once, for the multiplayer version of the game. The questionnaire consists of 12 Likert scale questions with 5 levels of agreement (strongly agree, agree, neutral, disagree, strongly disagree) to measure the player interest level between the two versions of the game.

All the likert scale questions were coded by assigning a numerical value from 5 to 1. Positive statement questions were coded in the following manner (strongly agree = 5, agree = 4, neutral = 3, disagree = 2, strongly disagree= 1).Negative statement questions were assigned in the following manner (strongly agree = 1, agree = 2, neutral = 3, disagree = 4, strongly disagree= 5).An overall score for each filled questionnaire was calculated.

In figure 11 below it can be observed that the mean score of the single-player version of the game (34.0) is lower than the mean score of the multiplayer version of the game(43.2). Furthermore, it can be observed that the standard deviation (SD) of the multiplayer version is higher than the single-player version.

Descriptives								
							Shapiro-Wilk	
TypeOfPlay	N	Mean	SD	Minimum	Maximum		W	p
Score	SinglePlayer	1	34.0	3.3	29	42	0.91	0.19
		4		5			7	6
	MultiPlayer	1	43.2	4.8	32	52	0.93	0.38
		4		1			7	5

Figure 11: Mean questionnaire score of game versions.

5.2.1 Normality Of Questionnaire Data

A test of normality (Shapiro Wilk test) was done to determine if the data are normally distributed or not. As can be seen in figure 12 below, no support is evident for the hypothesis that the data are non-normally distributed.

Normality Test (Shapiro-Wilk)				
			W	p
Score-SinglePlayer	-	Score-Multiplayer	0.949	0.539
Note. A low p-value suggests a violation of the assumption of normality				

Figure 12: Shapiro Wilk normality test of questionnaire score.

5.2.2 Order Effect In Questionnaire score

After testing the normality of data, the data is then checked for any significant order effect by conducting the between-group t-test. The result of the between-group t-test as shown in figure 13 below shows that the p-value is greater than the significance level, indicating that the difference between the two groups is not statistically significant. Hence, no evidence has been found suggesting that there is an order effect.

Independent Samples T-Test				
		Statistic	df	p
PlayTime	Student's t	-0.0896	26.0	0.929

Figure 13: Independent Samples T-Test Result.

5.2.3 Questionnaire Score Between Two Versions

Since the questionnaire data are normally distributed and there are no order effects induced by the order of gameplay. The main hypothesis was tested by conducting the within-groups t-test on questionnaire data. The overall score was used as a dependent variable and the "type-of-play" was used as an independent variable having two categories (*Single-player and multiplayer version*).

In figure 14, it can be observed that the p-value is $<.001$ which is less than the decision criterion (0.05) which means that we can reject the null hypothesis (H_0) which states "*There is no statistically significant difference in the level of player interest between the two versions of the game*". Because the null hypothesis is rejected, the hypothesis that the multiplayer version of the game is more interesting than the single-player version of the game receives more support.

Paired Samples T-Test				
		statistic	df	p
Score-SinglePlayer	Score-Multiplayer	Student's t	-6.76	13.0
				$<.001$

Figure 14: Paired Samples T-Test Result.

5.3 Qualitative Data Results

A small portion of qualitative data was also gathered and analyzed by sending two open-ended questions to all participants. The questions were sent to participants at the end of the experiment after they have played both versions of the game. All participants answered the questions and almost all of the answers were one or two sentences long. The following are the 2 qualitative questions which were asked:

- Between the two versions of the game (single-player and multiplayer version), why do you think one version is more enjoyable than the other?
- Between the two versions of the game (single-player and multiplayer version), why do you think one version keeps your interest in the game to play more?

The answers to both questions were mostly similar, this is perhaps due to the two overlapping/similar concepts, "interest" and "enjoyment". In summary, all the participants agreed that the multiplayer version is more enjoyable and interesting than the single-player version. The reasons put forward by participants are that multiplayer brings competitive and challenging situations in the game. Furthermore, playing with different people offers multiple levels of difficulty and different experience every time.

6 DISCUSSION AND FUTURE WORK

The primary purpose of this research study was to evaluate the following hypothesis "Addition of multiplayer functionality in HRTF audio games for visually impaired users will increase the level of player interest". The hypothesis is tested in three ways first by looking at gameplay data then the questionnaire score and finally the qualitative data. All three ways of testing pointed in the same direction providing support for the hypothesis.

The hypothesis that the addition of multiplayer functionality in an HRTF audio game for visually impaired users will increase the level of player interest did receive support in this study. Of course, no definite conclusions can be drawn from this

and these results mainly serve as an encouragement to investigate the issue further. Additional studies are needed, for instance studies looking at the stability of the present results by using different samples of users, if the results hold for visually impaired users, studies investigating different types of games and levels of game complexity etcetera. The results also point to that even games with very limited features and functionality perhaps could be enjoyed by players by the addition of multiplayer functionality. This also needs to be further investigated. Furthermore, it appears that it could be interesting to explore the many possibilities offered by 3D audio even in more advanced multiplayer games.

Existing games for the visually impaired are very few and technological advancements in graphics and media technology has further slower the development of such games. This is unfortunate for many reasons but most importantly, the people who can be benefited the most are ignored. This is perhaps because of the less profitable market. The developed game is a good example of an accessible inclusive game. Inclusive games can potentially be more profitable for developers and include people with impairments. Additionally, the research on accessible games is highly focused on the development of either educational or utility apps. Entertainment and enjoyment are largely ignored, especially the topic of making enjoyable and interesting games for people with serious visual impairment. Existing games are more of an educational or therapy tools rather than actually being a game. This study is unique in itself as the focus of this research study is enjoyment and interest, it is unclear if any research study with such focus exists.

6.1 Limitations

The scope of this project only makes an initial evaluation of the hypothesis possible using only one type of game. The results and findings can be further expanded by testing the hypothesis with different types of games. Furthermore, participants are recruited using the convenience sampling method instead of random sampling and the factors such as participants interest in gaming or interest in specific type of games were not considered. The experiment was done with sighted participants with a virtual blindfold instead of visually impaired users and it is important to evaluate the hypothesis with people with severe visual impairment.

6.2 Game Genre

There are many genres of the games the four major categories mentioned by (Natkin, 2006) are action games, adventure games, puzzle games and strategy games[18]. Some games such as simulation and management games offer complex mechanics and are more textual than others. Hypercasual-games is an emerging genre of games and is targeted toward players of all ages. Hypercasual games offer simple controls mostly just tapping on the screen yet still offers an enjoyable experience. The game developed for testing the hypothesis falls under the category of hypercasual games and goes one step further by the inclusion of HRTF audio and multiplayer to make it accessible for people with serious visual impairment. Development in making enjoyable and interesting games can be benefited largely by focusing on inclusive games in general and especially hypercasual games with the inclusion of multiplayer functionality.

ACKNOWLEDGMENTS

I would like to express my special thanks of gratitude to my Supervisor Prof. Mats Lind of Uppsala University for his guidance and support. I would also like to extend my gratitude to all the people who took part in survey. Last but not the least, I would like to thanks my parents without them none of this would indeed be possible.

REFERENCES

- [1] Archambault, D., Ossmann, R., Gaudy, T., & Miesenberger, K. (n.d.). Computer Games and Visually Impaired People. Upgrade.
- [2] Buaud, A., Svensson, H., Archambault, D., & Burger, D. (2002). Multimedia Games for Visually Impaired Children. In K. Miesenberger, J. Klaus, & W. Zagler (Eds.), *Computers Helping People with Special Needs* (Vol. 2398, pp. 173–180). Springer Berlin Heidelberg. https://doi.org/10.1007/3-540-45491-8_38
- [3] Wilhelmsson, U., Engström, H., Brusk, J., & Östblad, P. A. (2017). Inclusive game design facilitating shared gaming experience. *Journal of Computing in Higher Education*, 29(3), 574–598. <https://doi.org/10.1007/s12528-017-9146-0>
- [4] Ackland, P., Resnikoff, S., & Bourne, R. (2017). World blindness and visual impairment: despite many successes, the problem is growing. *Community eye health*, 30(100), 71–73.
- [5] Vorderer, P., Hartmann, T., & Klimmt, C. (2003, January 1). Explaining the enjoyment of playing video games: The role of competition. *Proceedings of the Second International Conference on Entertainment Computing*. <https://doi.org/10.1145/958720.958735>.
- [6] Reinhard Pekrun and Lisa Linnenbrink-Garcia. 2014. *International Handbook of Emotions in Education*. Routledge.
- [7] Brockmyer, J. H., Fox, C. M., Curtiss, K. A., McBroom, E., Burkhart, K. M., & Pidruzny, J. N. (2009). The development of the Game Engagement Questionnaire: A measure of engagement in video game-playing. *Journal of Experimental Social Psychology*, 45(4), 624–634. <https://doi.org/10.1016/j.jesp.2009.02.016>.
- [8] Fitzgerald, A., Huang, S., Sposato, K., Wang, D., Claypool, M., & Agu, E. (n.d.). The Exergame Enjoyment Questionnaire (EEQ): An Instrument for Measuring Exergame Enjoyment. 10.
- [9] Games and Activities. (n.d.). The American Foundation for the Blind. Retrieved January 27, 2022, from <https://www.afb.org/node/16207/games-and-activities>.

- [10] Archambault, D., Ossmann, R., Gaudy, T., & Miesenberger, K. (n.d.). Computer Games and Visually Impaired People. 21.
- [11] Playing in the dark. (n.d.). Retrieved January 25, 2022, from <https://www.playinginthedark.net/topspeed3/>.
- [12] Mustaquim, M. M. (2013). Automatic speech recognition- an approach for designing inclusive games. *Multimedia Tools and Applications*, 66(1), 131–146. <https://doi.org/10.1007/s11042-011-0918-7>
- [13] The Last of Us 2—Blind Accessibility Review. (2020, June 18). Can I Play That? <https://caniplaythat.com/2020/06/18/the-last-of-us-2-review-blind-accessibility/>
- [14] The Last of Us Part II - Accessibility. (n.d.). PlayStation. Retrieved May 5, 2022, from <https://www.playstation.com/en-us/games/the-last-of-us-part-ii/accessibility/>
- [15] Smith, B. A., & Nayar, S. K. (2018). The RAD: Making Racing Games Equivalently Accessible to People Who Are Blind. *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, 1–12. <https://doi.org/10.1145/3173574.3174090>
- [16] Bălan, O., Moldoveanu, A., Moldoveanu, F., Nagy, H., Wersényi, G., & Unnórsson, R. (2017). Improving the Audio Game–Playing Performances of People with Visual Impairments through Multimodal Training. *Journal of Visual Impairment & Blindness*, 111(2), 148–164. <https://doi.org/10.1177/0145482X1711100206>
- [17] Home | RSGames—Accessible Games for the Blind. (n.d.). Retrieved May 10, 2022, from <https://rsgames.org/>
- [18] Natkin, S. (2006). *Video Games and Interactive Media: A Glimpse at New Digital Entertainment*. A K Peters/CRC Press. <https://doi.org/10.1201/9780367807115>
- [19] Paavilainen, J., Hamari, J., Stenros, J., & Kinnunen, J. (2013). Social Network Games: Players’ Perspectives. *Simulation & Gaming*, 44(6), 794–820. <https://doi.org/10.1177/1046878113514808>
- [20] Raith, L., Bignill, J., Stavropoulos, V., Millea, P., Allen, A., Stallman, H. M., Mason, J., De Regt, T., Wood, A., & Kannis-Dymand, L. (2021). Massively Multiplayer Online Games and Well-Being: A Systematic Literature Review. *Frontiers in psychology*, 12, 698799. <https://doi.org/10.3389/fpsyg.2021.698799>
- [21] Alsén, A., Runge, J., Drachen, A. and Klapper, D. 2021. Play With Me? Understanding and Measuring the Social Aspect of Casual Gaming. *Proceedings of the AAAI Conference on Artificial Intelligence and Interactive Digital Entertainment*. 12, 2 (Jun. 2021), 115-121.

A APPENDICES

Appendix 1 – Introduction Document For Participants

Hi, *Participant Name*

First of all, thanks for participating in this research study. In this document, I want to briefly introduce my research study, why it is important and your particular role.

TheProblem

As we all know that visually impaired people cannot actively participate in many fun activities as compared to sighted users. Video games in particular are an excellent source of enjoyment as they provide an immersive experience using 2d and 3d graphics and frequent updates in graphics keep players motivated for a longer period of time. There are a very limited amount of games for visually impaired players and mostly they are audio games with audio instructions to help players play the game. However, one potential problem with such games is that players might lose interest after some time. There are limited ways in which to evolve these games to keep the players interested as compared to games developed for sighted players.

Goal

The goal of this research study is to investigate how can we make video games more enjoyable and retain players' interest for a longer period of time. This research study will significantly help make video games more enjoyable for people with visual impairment.

YourRole

Your participation in this research study is very important in fact, the success of this research study solely depends on your active participation.

Task

You will be provided with two versions of the game (singleplayer and multiplayer). The game is based on HRTF audio so it requires the use of handsfree to play the game otherwise the game is not playable. The game screen is simply a black screen to mimic the visually impaired person and without any graphics, so you can better focus on just the audio. Further specific instructions regarding gameplay will be shared along with the game(i-e the tutorial in the game application) and if you have any questions please email me at saadfiver4@gmail.com. You will be assigned to either GroupA or GroupB. If you are assigned to GroupA you have to play the single-player version of the game for 7 days as much as you like to play and then play the multiplayer version of the game for another 7 days. If you are assigned to GroupB then you start with the multiplayer version of the game and after 7 days switch to the single-player version of the game. A survey will be sent to you to fill out via email after each 7 days period. Furthermore, the game will record gameplay time in a log file which you have to email me. No Personal Data will be collected and shared.

Appendix 2 – Gameplay Time Data Of Two Groups Of Participants (Stm And Mts)

	GROUP A - STM (SINGLE TO MULTIPLAYER)								GROUP B - MTS (MULTIPLAYER TO SINGLE-PLAYER)						
	SinglePlayer Version GamePlay Time (Minutes) of Each Participant								Multiplayer Version GamePlay Time (Minutes) of Each Participant						
	P1	P2	P3	P4	P5	P6	P7		P1	P2	P3	P4	P5	P6	P7
DAY 1	12	16	9	15	17	15	14		15	13	17	11	14	17	15
DAY 2	13	8	11	11	9	11	13		16	12	11	13	13	17	11
DAY 3	11	8	13	11	7	13	13		15	10	9	10	7	15	16
DAY 4	9	9	13	9	9	9	11		12	13	14	9	12	10	10
DAY 5	11	13	13	12	13	9	8		11	13	15	10	8	11	11
DAY 6	8	13	8	7	11	7	8		7	16	11	12	13	9	10
DAY 7	11	11	12	9	9	9	7		14	9	12	11	13	9	13
Total Time (Minutes)	75	78	79	74	75	73	74		90	86	89	76	80	88	86
Total Time (Seconds)	4500	4680	4740	4440	4500	4380	4440		5400	5160	5340	4560	4800	5280	5160
	Multiplayer Version GamePlay Time (Minutes) of Each Participant								SinglePlayer Version GamePlay Time (Minutes) of Each Participant						
DAY 8	13	15	17	16	25	15	10		10	11	9	5	13	9	11
DAY 9	16	12	13	14	9	17	13		8	11	9	3	8	13	13
DAY 10	13	10	13	12	7	13	18		11	10	11	8	6	10	8
DAY 11	10	9	14	14	13	11	9		9	9	11	9	9	8	10
DAY 12	11	13	11	12	8	8	13		8	13	15	7	11	5	11
DAY 13	9	12	9	12	7	11	8		10	13	14	7	14	13	9
DAY 14	11	11	10	9	13	9	13		11	10	7	9	9	11	11
Total Time (Minutes)	83	82	87	89	82	84	84		67	77	76	48	70	69	73
Total Time (Seconds)	4980	4920	5220	5340	4920	5040	5040		4020	4620	4560	2880	4200	4140	4380
	STM = Single-Player To Multiplayer Group														
	MTS = Multiplayer To Single-Playeer group														

Appendix 3 – Questionnaire Response Of Each Participant For Both Versions Of The Game

First Column shows the group to which the participants belongs to.

GroupA = Single-Player To Multiplayer

GroupB = Multiplayer To Single-Player

Second Column Represents the version of the game for the questionnaire was filled out.

Column E to P represents the likert score response value for each question.

Final Column Q is the total calculated score for each filled questionnaire.

► B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
GROUP	GameVersion	AGE	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Score
Group A	SinglePlayer version	27	3	3	2	3	2	1	4	5	3	2	3	4	35
Group A	SinglePlayer version	27	2	3	2	4	3	1	4	3	3	3	4	3	35
Group A	SinglePlayer version	29	2	2	2	3	1	1	3	4	4	2	2	3	29
Group A	SinglePlayer version	27	2	3	3	3	1	1	3	3	4	4	4	3	34
Group A	SinglePlayer version	29	3	3	3	4	1	2	4	4	3	4	2	3	36
Group A	SinglePlayer version	29	3	4	2	3	1	1	3	4	4	4	2	1	32
Group A	SinglePlayer version	29	1	2	2	3	1	3	4	4	2	2	3	2	29
Group A	MultiPlayer Version	27	4	4	4	4	3	3	5	5	5	4	4	4	49
Group A	MultiPlayer Version	27	4	4	3	4	3	3	5	4	4	4	4	3	45
Group A	MultiPlayer Version	29	4	3	4	4	2	2	4	5	5	4	4	3	44
Group A	MultiPlayer Version	27	3	4	4	4	3	1	4	5	5	4	5	4	46
Group A	MultiPlayer Version	29	4	5	3	3	4	2	4	4	4	4	4	2	43
Group A	MultiPlayer Version	29	3	4	3	4	3	1	4	4	5	4	3	3	41
Group A	MultiPlayer Version	29	3	5	3	3	2	1	4	4	4	4	4	4	41
Group B	SinglePlayer version	27	3	4	2	3	2	1	4	4	3	3	4	3	36
Group B	SinglePlayer version	26	4	4	4	4	3	1	4	4	4	4	4	2	42
Group B	SinglePlayer version	29	2	4	2	4	2	1	3	4	4	2	3	3	34
Group B	SinglePlayer version	27	3	3	3	4	2	1	3	3	4	3	4	3	36
Group B	SinglePlayer version	27	4	3	2	3	1	1	3	4	3	2	3	2	31
Group B	SinglePlayer version	27	2	3	3	3	1	1	3	4	2	3	3	4	32
Group B	SinglePlayer version	27	2	3	3	4	2	1	4	4	3	3	3	3	35
Group B	MultiPlayer Version	27	4	4	4	4	2	2	5	4	5	4	4	3	45
Group B	MultiPlayer Version	26	3	4	4	4	2	1	4	4	4	4	5	4	43
Group B	MultiPlayer Version	27	2	4	2	4	2	1	3	4	4	4	3	4	37
Group B	MultiPlayer Version	29	3	4	3	4	2	2	4	5	5	4	4	4	44
Group B	MultiPlayer Version	27	3	4	4	3	2	2	4	5	4	4	4	4	43
Group B	MultiPlayer Version	27	2	3	2	3	2	1	3	4	3	3	3	3	32
Group B	MultiPlayer Version	27	4	4	3	4	4	4	5	5	5	4	5	5	52

Blind Racing-survey

* Required

1. What is your assigned group? *

Mark only one oval.

- ☐ Group A (single-player to Multi-Player)
☐ Group B (Multi-Player to single-player)

2. For which version of the game you are filling the survey? *

Mark only one oval.

- ☐ SinglePlayer version
☐ MultiPlayer Version

3. Please state you age in Years. *

survey

4. I felt like I lost track of time while playing

Mark only one oval.

- ☐ Strongly Agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly Disagree

5. I did not feel like I wanted to keep playing.

Mark only one oval.

- ☐ Strongly disagree
☐ Disagree
☐ Neutral
☐ Agree
☐ Strongly agree

6. I played longer than I meant to.

Mark only one oval.

- ☐ Strongly Agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly Disagree

7. I can't tell that I'm getting tired

Mark only one oval.

- ☐ strongly agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly Disagree

8. Time seems to kind of standstill or stop.

Mark only one oval.

- ☐ strongly agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly Disagree

9. I lose track of where I am.

Mark only one oval.

- ☐ strongly agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly Disagree

10. I really get into the game

Mark only one oval.

- ☐ strongly agree
☐ Agree
☐ Neutral
☐ Disagree
☐ Strongly Disagree

11. I was focused on the game

Mark only one oval.

- ☐ strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

12. I felt that this game provided an enjoyable challenge

Mark only one oval.

- ☐ strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

13. I felt a sense of accomplishment from playing the game

Mark only one oval.

- ☐ strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

14. I did not feel a desire to make progress in the game.

Mark only one oval.

- ☐ strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

15. I don't answer when someone talks to me while playing the game.

Mark only one oval.

- ☐ strongly agree
- ☐ Agree
- ☐ Neutral
- ☐ Disagree
- ☐ Strongly Disagree

This content is neither created nor endorsed by Google.

Google Forms