Blind Hero: Enabling Guitar Hero for the Visually Impaired

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ABSTRACT

Very few video games have been designed or adapted to allow people with vision impairment to play. Music/rhythm games however are particularly suitable for such people as they are perfectly capable of perceiving audio signals. Guitar Hero is a popular rhythm game yet it is not accessible to the visually impaired as it relies on visual stimuli. This paper explores replacing visual stimuli with haptic stimuli as a viable strategy to make games accessible. We developed a glove that transforms visual information into haptic feedback using small pager motors attached to the tip of each finger. This allows a blind player to play Guitar Hero. Several tests have been conducted and despite minor changes to the gameplay, visually impaired players are able to play the game successfully and enjoy the challenge the game provides. The results of the study also give valuable insights on how to make mainstream games blind-accessible.

Categories and Subject Descriptors

H.5.2 [**Information Systems**]: User Interfaces - Haptic I/O; K.8.0 [**Computing Milieux**]: Personal Computing - Games

General Terms

Human Factors, Measurement, Design, Experimentation

Keywords

Game Accessibility, Visually Impaired, Blind, Haptic

1. INTRODUCTION

Research on technology for visually impaired people has primarily focused on web accessibility [5] and assistive technology [15, 13]. There are approximately 10 million blind and visually impaired people in the United States, including an estimated 1.3 million people who are legally blind and 1.5 million who use regular computers [1]. Research has focused on helping people with visual impairments to improve their reading, orientation and mobility skills. They are also trained to lead more independent and productive lives by including them in our information society. Studies conducted in assistive technologies with regard to vision are in great demand as our population ages and more people suffer from age related vision loss. Over the last several decades, video games have become a very popular form of entertainment. According to a 2008 report by NPD, 63% of the U.S. population plays some sort of computer and/or video games where over 51% of these players play games on a weekly basis [9]. Despite this increased interest in games, very few games are actually accessible to the visually impaired. Being able to play a game is a quality of life issue that, especially for younger people, may affect their psychological well being.

Games are popular because of the high degree of interaction they offer. Unlike watching a movie or reading a book, games provide two-way interaction where players actively participate and their choices may affect game outcomes. Games are mainly designed for entertainment, which puts one major constraint on the way people interact with them: it must be fun. This is different from the requirements of interacting, for example, with a web browser or a word processor, which are designed to help the user perform productivity-related tasks.

Games currently rely on the ability of players to see their screens. However, there are new strategies to help replace these visual components. Most games provide feedback through visuals, e.g. by rendering pixels, one can indicate the presence of an enemy. Sound is also used to provide feedback (e.g. gunfire might also be an indication of an approaching enemy). Still, games rely primarily upon being able to see visuals and most games cannot be played using sound alone. This is clearly a problem for the visually impaired, because they cannot get this type of feedback from the game. One of the strategies that we use in this paper is replacing stimuli. Games provide stimuli in the form of visual, audio, and haptic feedback. Depending on this feedback, the player provides input which may change the state of the game. The game provides feedback again and the process is repeated for the remainder of the game. If a player is unable to perceive a particular stimuli, either because the player is deaf or blind, one strategy is to replace that missing stimulus with a stimulus that the player can perceive. For example, closed captioning is a technique that replaces a game's audio feedback with visual feedback to make it accessible to those with hearing impairments. Without closed captions, players with auditory disabilities are unable to hear things like the footsteps of someone sneaking up from behind or

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gunfire, which may lead to frustration and reduced enjoyment of the gaming experience. Closed captions have been successfully implemented in the popular first person shooter game Half-Life 2, which has been praised by the deaf gamers community for adding this feature.

Developing games is expensive and risky. It is more cost-effective, in terms of effort, to modify an existing game and make it accessible than it is to develop a brand new accessible game from scratch. In this paper, we are introducing Blind Hero, a modification of an existing game based on the popular video game Guitar Hero. Blind Hero transforms visual stimuli into haptic stimuli to allow visually impaired individuals to play a Guitar Hero-like game. We want to find out if this haptic version of the game can bring the same level of entertainment to blind people as it does to sighted players and whether replacing stimuli is a viable strategy to making games accessible in general.

The rest of the paper is organized as follows: The next section discusses related work and provides more background on the game we modified. Section 3 presents our implementation of the game. This is followed by the results of our usability study with 12 players in section 4. Section 5 discusses some unsolved problems with the implementation. Conclusions and future solutions are proposed in section 6.

2. BACKGROUND AND RELATED WORK

Many audio games recognized in [10, 4] are designed to provide auditory instructions and non-speech sound commands for blind people to control the game. Most of these games are simple arcade, puzzle, or racing games entirely controlled by audio commands.

AudioQuake [3] and Terraformers [17] are first person shooter, mainstream games that have been made blind-accessible. AudioQuake replaces visual feedback based on the idea of "earcons", which are types of structured sounds, often obeying musical conventions. They are designed to alert the player to an object or event, though they do not "sound like" their referents in the real-world [3]. However, learning the mappings between the sound effects and real-world objects is not that difficult. AudioQuake uses stereo sound to help the character navigate. For example, a sound to the left or right indicates if a wall, door, or other obstacle is present near the player and in which direction. Sounds gets louder as a player moves closer to an object. Arrow keys are used to move and turn with some customizable options to help players control their characters. Terraformers uses a 3D sound response system. The main character can either be navigated using the visual display (which also has a high-contrast setting for low-vision players) or sound. There is a tone that represents North and different variations of the tone to represent 8 compass points. The player can tell what is in front of the player by using a sound radar. By using a "ping" it is possible to tell how far objects are in front of the character. Using a key on the keyboard, it is also possible to tell what type of object is in front of the character, using a voice playback system.

Music/rhythm games are suitable for the blind as they already rely on audio as major feedback mechanism. Dance Dance Revolution (DDR) is a popular rhythm game where the player provides input by dancing on a large mat trying to match step instructions shown on the screen while the song plays. An accessible version of DDR has been developed for the blind, called Finger Dance [16]. There are high

Figure 1: Guitar Hero & Frets on Fire

and low pitched drum-roll sounds coming from either left or right speakers that consist of four output elements. Instead of four arrow step instructions in DDR, Finger Dance maps the four distinguishable sound to four keys on the keyboard for players to control. This is of course a significant departure from the original gameplay of DDR. AudioOdyssey [11] is another music/rhythm game that uses a Wii-mote controller and that can be played by sighted as well as non-sighted players. It provides instructions and feedback entirely through audio. Our approach is related to the two aforementioned games as it is also a music/rhythm game.

Guitar Hero is a popular rhythm game developed by Red Octane, that lets the player use a guitar-shaped controller with various colored buttons to simulate the playing of rock music. More than 14 million copies have been sold of this game to date [12]. The goal of this game is that the player must press the right button combination matching the colored dots on the screen, which are moving along with the music. Some dots have lines attached to them, implying that one should hold down that corresponding button for a longer period of time: until the end of the line hits the bottom of the screen (See Figure 1). When a player hits the right combination of buttons matching the dots on the screen, the score increases.

Despite unsuccessfull predecessors, Guitar Hero became a million dollar franchise and has dominated the sales charts for the past 2 years. If we break down the interaction between the player and the game, we can make the following observations. The game continuously provides visual stimuli (dots and lines on the screen), which the player uses to know when to press certain buttons on the controller. If the player presses the correct combination it will hear the correct guitar riff for that part of the song.

Because Guitar Hero is closed source we cannot make any changes to the game. Frets on Fire[19] is an open source clone of Guitar Hero that is written in Python and runs on Linux, Mac, and Windows. Since we are mainly interested in exploring whether we could make this style of game accessible to the vidually impaired, starting with Frets on Fire reduced the amount of development overhead required to run our experiments.

The amount of feedback provided through visuals in Guitar Hero is relatively small. This makes the game a good candidate to apply the "stimuli replacement" technique. However, we cannot turn Guitar Hero into an audio game because of the predominance of the focus on musical sound already in the game. Hence, haptic feedback seems most suitable.

Haptic interfaces generate mechanical signals that provide information via sense of touch, which is much less commonly lost, compared to the sense of vision [18]. This technique is mostly adopted in medical fields and with assistive technologies. In some cases, non-visual (e.g. auditory or haptic) and multimodal (bi- and trimodal) feedback forms demonstrate significant performance gains over visual feedback forms [14] for both Age-Related Macular Degeneration (AMD) and normally-sighted users. Some scholars even argue that haptic-only feedback is more beneficial than auditory-only feedback [6, 2]. Haptics are also used to convey spatial information such as size and location [8].

3. BLIND HERO

The first thing we created was a device that was able to provide haptic feedback.

3.1 Hardware

The design of the glove was motivated by being able to preserve as much of the original interaction as possible. The idea was to use small "pager" motors, most commonly found in pagers and cell phones, to provide haptic feedback. Ideally, one motor would represent each of the five colored buttons on the guitar controller. Whenever a pager motor buzzes the corresponding button must be pressed. Initially, we explored placing pager motors underneath each button on the guitar controller. However, the feedback of the pager motors turned out to be so strong that the whole guitar vibrated and players could not distinguish which button needed to be pressed. Therefore, we decided to mount the pager motors on the fingers of a special glove that the player would wear while playing the game. The original Guitar Hero controller has 5 buttons that the player operates using only four fingers. When it comes to the dots on the fifth "fret", the hand position must shift down to cover the last button. The design of the guitar makes it very hard to press the fifth button with the thumb. We cannot attach more than one motor to each finger. This leaves no option other than using only the four buttons and having to ignore the dots on the fifth fret. In our user studies, we used four 7mm in diameter, 12.5mm long pager motors attached on each of the four fingers of a left hand glove. These motors are rated 1.3 volts DC at 70 milliamps. FT232R is a USB to serial UART (Universal Asynchronous Receiver/Transmitter) interface with optional clock generator output, and asynchronous and synchronous bit bang interface modes. This chipset, released by Future Technology Devices International (FTDI), allows us to control each motor through a USB port. The port shows up as a virtual com port handling communication between the application and the device. Figure 2 shows what our glove looks like.

3.2 Software

We modified Frets on Fire to send a message to the virtual com port indicating which pager motor must vibrate and for how long. The problem here was that we needed to precisely time when to start a pager motor. Players can respond faster to visual stimuli than to haptic stimuli. It will also take a while for the pager engine to operate at full speed. It will take the player some time to notice when a pager engine has started vibrating and so we needed to build in a delay e.g. the pager needs to start buzzing slightly earlier than the player needs to press the note. This delay needed to be determined accurately because if the delay was too short the player would not be able to respond fast enough, resulting in missing notes. If the delay was too long the player may press the button too early, also resulting in missing notes

Figure 2: Haptic Glove

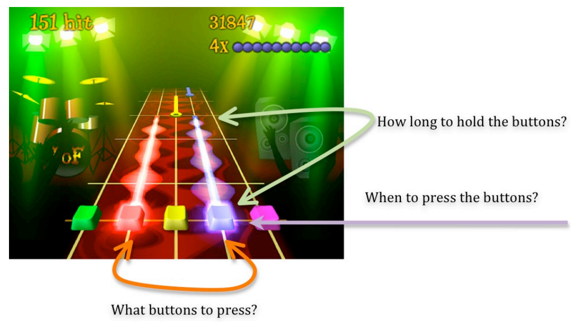

Figure 3: Game Tasks

and potentially missing dots that are close by afterwards. A quarter of a second delay time was chosen based on the shortest time distance between every two dots of music notes and corresponds to average human reaction time. We came up with the following game tasks (See Figure 3) and corresponding haptic feedback to send to the virtual com port (See Table 1).

4. USABILITY STUDY

"You can't control what you can't measure" [7] is a well known statement in software engineering, which is also applicable to game accessibility. What are the metrics for measuring if a game is accessible? No set of accessibility guidelines for games similar to the W3C web content accessibility guidelines exists. Games are different from regular software as they require an additional constraint on what the interaction should provide: games should be fun. Measuring "fun" is not a simple endeavor since that is a subjective measure depending on player preference.

Table 1: List of Tasks & Solutions

Tasks	Haptic Feedback
When to press the buttons?	Start Vibration 1/4 seconds before the screen moves onto the dots.
Which buttons to press?	Vibrating the corresponding pagers attached to the right finger to press.
How long to hold those buttons?	Vibration lasts the length of each note.

Figure 4: A blind player playing Blind Hero

The "Beyond Accessibility to Efficiency" (BATE) principle states that the goal of assistive technology should be more ambitious than simply to provide access[13]. A user with a disability should be able to perform a task with the same efficiency as anyone else. Our application must bring the same level of entertainment to people with disabilities as without disabilities. For the Blind Hero user study we split the evaluation into two parts:

- **Quantitative** oriented analysis: we collected raw data including players' game score, accuracy percentages, and hardware effectiveness during the game play. Objectively measuring these components allows us to analyze how well a disabled player is able to play the game and observe his/her learning curve and improvement ratios.

- **Qualitative** oriented analysis: is the game fun to play? If the game fails to provide a fun and engaging experience no one will want to play the game and the game loses its purpose, despite players being able to use it efficiently for a task. Through a questionnaire we asked players whether or not the game is fun.

Many different types of sighted and visually impaired players were involved in this study to create a broad range of experiences and to be able to compare performances.

4.1 Participants

All participants were new to the Blind Hero game. Some participants, however, are expert Guitar Hero players, whereas some have never played Guitar Hero before (See Figure 4). All the sighted players are blindfolded when playing Blind Hero. The players were stratified into four, three person groups based on visual acuity and the game they had to play (See Table 2). The questions that needed to be answered for these groups are:

- Will visually impaired individuals have the same gameplay experience with Blind Hero as sighted users have with Guitar Hero?

- Which group will do better on Blind Hero among groups 1, 2, and 3?

Table 2: Group Description

Group #	Vision Acuity	Game to Play in Experiment	Guitar Hero Experience
1	Sighted (Blindfolded)	Blind Hero	New
2	Blind	Blind Hero	Inaccessible
3	Sighted (Blindfolded)	Blind Hero	Expert
4	Sighted	Guitar Hero	New

Table 3: Song Playing Order & Labels

Music #	Song	Repetitive Count	Label
1	Song 1	1	1-1
2	Song 2	1	2-1
3	Song 1	2	1-2
4	Song 1	3	1-3
5	Song 1	4	1-4
6	Song 2	2	2-2
7	Song 2	3	2-3
8	Song 2	4	2-4

4.2 Collected Data Analysis

The accuracy percentile over short and long dots, for each song played, is calculated for each player during the game. In general, players start on the easy level when they play a game for the first time. We picked relatively easy songs for our participants to test. On the easiest level, no more than one button has to be pressed simultaneously throughout the whole game. Each song comes with 3 or 4 different levels of difficulty, with the harder levels requiring more buttons to be pressed simultaneously. Different songs vary significantly with regard to rhythm, speed, and the occurrence of patterns in the music. Because of this, when playing different songs, one is likely to end up with very different accuracy rates, even on the same difficulty level. By only playing two different songs repeatedly (see Table 3) we were able to measure players' performance increases for each song. Each song takes approximately three to four minutes to complete and our participants were able to finish playing the whole set in less than 40 minutes. After finishing the set we asked them to fill out a brief questionnaire collecting qualitative feedback on varying aspects of playing Blind Hero.

Figure 5 a) - d) shows the average accuracy level (e.g. how many dots they got right) over these two songs as defined in Table 3. All groups show a similar performance difference between song 1 and 2. Song 2's lower accuracy for all groups indicates that this song is more difficult to play. Looking at each song individually we see, for all groups, that the accuracy increases after each time playing the song. Comparing the accuracy percentage for all four groups, we have the following observations: While playing Blind Hero, sighted individuals with no experience with the original Guitar Hero game had the worst level of performance in our study. Visually impaired players had much better performance than the previous group. Group 3, which includes sighted players that have already played Guitar Hero before, performed slightly better than the group of blind players. We also compared sighted players playing the original Guitar Hero game for the first time. They had the highest levels of accuracy among all groups.

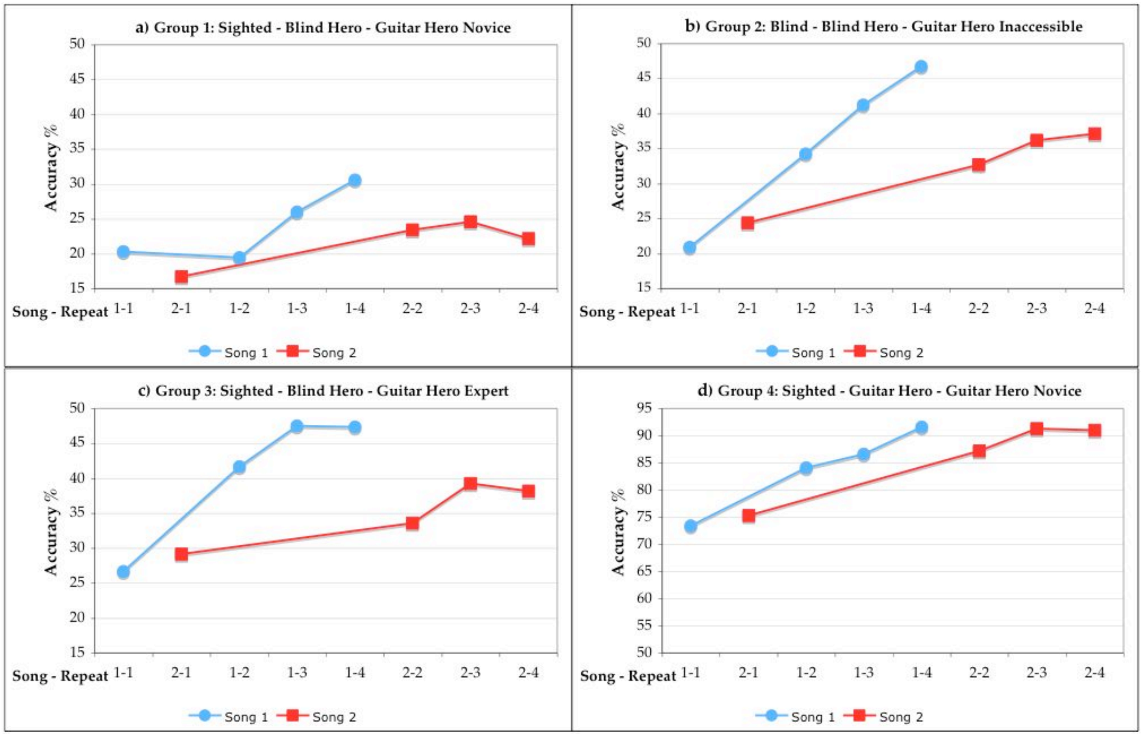

Figure 5: Average Performance for each group playing songs 1 & 2.

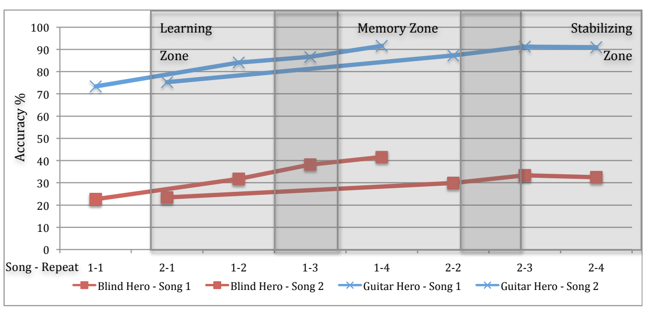

Figure 6: Guitar Hero vs. Blind Hero.

Another interesting observation that can be drawn from Figure 5 is that all groups' performance levels follow similar curve patterns. For both songs, it takes the player a while to learn to play the game and increase their performance. In the very beginning, the accuracy percentages are relative similar and low. After that, performance starts to increase significantly each time a song is played.

Based on the results we found, we have generated another chart that shows performance in Blind Hero by combining groups 1-3 and comparing against the results with Guitar Hero by group 4. The comparison results are split into different zones (see Figure 6) explained as follows:

1. **Learning Zone:** hardware including the guitar controller and the glove are new to the participants that play Blind Hero and it will take a while for them to get accustomed to feeling which pager vibrates and for how long. The first minutes of the first song are to get used to the haptic glove. For Guitar hero this is similar e.g. they have to learn what the dots mean on the screen and how long they have to press the button by watching the screen carefully. All of the players will then learn when and what button to press by either following the glove's vibration or visual observation. The feedback for both games is the same; when the player presses the correct button; a guitar riff will play corresponding to that part of the song. This predominance of music is the reason why replacing visual stimuli by audio is not an option.

2. **Memory Zone:** at some point, players start recognize patterns that correspond to specific parts of the music such as the chorus or solos. From recognizing patterns in the music, the player is then able to play parts from memory rather than by haptic input. We see a big performance increase in the transition between learning and playing from memory. Sometimes however, when relying on memory and ignoring the haptic inputs, players actually hit the correct notes too early, decreasing their performance rating. We realized that the glove is able to translate visual stimuli into haptic stimuli as it contributes to the memorization process and allows players of Blind Hero to feel-then-act, rather than visualize-then-act as sighted players of Guitar Hero do.

3. **Stabilizing Zone:** after 30 minutes of playing the game, the performance of all groups starts to stabilize. Some performance ratings may have even slightly decreased from one song to the next due to fatigue. The limits of players short-term memories were reached and further improvements in skill level might take longer-term practice with the game.

After playing the 8 songs, we gave each player a questionnaire focused on identifying whether this was a fun game to play. We received all positive feedback, despite the setup of our test requiring players to play the same songs repeatedly. Over the duration of the songs, we noticed players were enthusiastically trying to increase their performance, so the elements of challenge and progress is definitely present in our game. Players were convinced they could improve their performance given enough practice. Overall all, the players in the study were very impressed with the game.

5. DISCUSSION

The development of Blind Hero and the results of the study have given us valuable insights into whether replacing stimuli is a viable technique to make games accessible. We made the following observations:

5.1 Compromising Gameplay

There is not a one-to-one mapping when transferring feedback from the visual domain to the haptic domain. The level of detail that the eye can separate including colors, shape, motion is a much higher level than what the sense-of-touch can differentiate. For Blind Hero we tried as much as possible to preserve the gameplay, as it is with Guitar Hero. Nevertheless, because there is not a one-to-one mapping, we had to make the following compromises:

- **Lookahead:** in Guitar Hero, the dots on the frets move from top to bottom leaving future dots on top of the current playing ones. Sighted people can see a whole screen of dots during the play, which gives them time to prepare which buttons to play next. For our haptic glove we only provide direct feedback on the button that needs to be played and we don't provide this type of lookahead information. We explored the use of additional motors for providing lookahead information, but this made the gameplay overly complicated, and would likely take players a longer time to learn. We compromised gameplay by not providing any lookahead information. This is the main reason that people score higher playing Guitar Hero than Blind Hero.

- **One Button Less:** as stated in Section 3, we carefully chose to only use four buttons out of five on the guitar. This will not affect any songs played at easy or medium levels, since the fifth fret is not used. The hard level uses the fifth fret and our glove currently cannot accommodate that. We are convinced that this compromise is acceptable, especially since all of our participants indicated that the current level of interaction is appropriate, which as players get more experienced may change.

In implementing these compromises and departing from the original Guitar Hero gameplay, we run the risk of creating a game experience that is not fun. Hence, compromising decisions must always try to optimize gameplay. We did not know how to provide lookahead information. Providing lookahead information through the use of extra pager motors was a solution we considered but that would most likely not be an enjoyable experience because of the steep learning curve. In this case we decided to get rid of the lookahead information all together, to make sure the game is easy to learn. Despite the compromises, we have the impression that Blind Hero is a very close representation of Guitar Hero.

5.2 Hardware Cost

For this game, we had to create a customized glove that players need to use to be able to play the game. The glove we developed cost about $1500 including custom design, hardware, and manual labor. Even with possible cost reduction when mass produced, cost may still be a barrier to the success of this game. In the future we might explore more cost-effective solutions, such as the use of headphones where the music could be playing in one ear while the other ear gets audio cues indicating which note to play. However, currently our haptic device can provide about 200 different stimuli; e.g. four frets, and dots varying in length. Using audio cues will require more research as players may have a hard time distinguishing different audio cues. Another viable option could be using a Force Feedback mouse and adapt the game accordingly.

5.3 Glove Design

Each motor is currently mounted just below the last joint on the finger. However, since players may have different sized hands, we need to find a solution that allows for customization of the glove to fit most peoples' hands. Initially we attached the pagers below the second last joint on each finger, which made it hard for players to identify which finger was buzzing. A glove where pagers could be attached anywhere on the finger would be optimal as it would allow the player to place the motors such that they could more accurately identify which finger is buzzing. This would be especially useful for songs that require one to play two notes at the same time, when it becomes harder to identify which finger is actually buzzing.

5.4 Short Dots vs Long Dots

The dots of the song come with different lengths. As part of our data collection, we did an analysis on the accuracy of long dots versus short dots using data from all groups. For all groups that played Blind Hero, players made almost twice as many long dots as short ones, while in the Guitar Hero game, the accuracy over long dots is just slightly higher than the short ones. We noticed that for shorter dots, the motor tends to generate weaker vibrations i.e. less effective to the player to make a move. This is because the duration of a pager's vibration affects the motor power level. We should be able to find another type of motor or alter the program to treat dots lengths the same cross the whole game in the future, or find a way to weaken the signal the pager sends for the longer notes so the shorter dots will be more easily distinguishable from longer dots.

5.5 The "Misconception"

A common notion is that blind people might have better senses of hearing and touch than sighted people because the loss of vision improves their other senses. Some think it is a misconception, others don't. What does this study with Blind Hero contribute to this statement? The performance comparison reveals that, when looking at the blind group's accuracy level and comparing it against average of group 1&3, blind people do have some level of advanced performance as shown in Figure 7. One interesting comment from one of our blind participants was that "Your

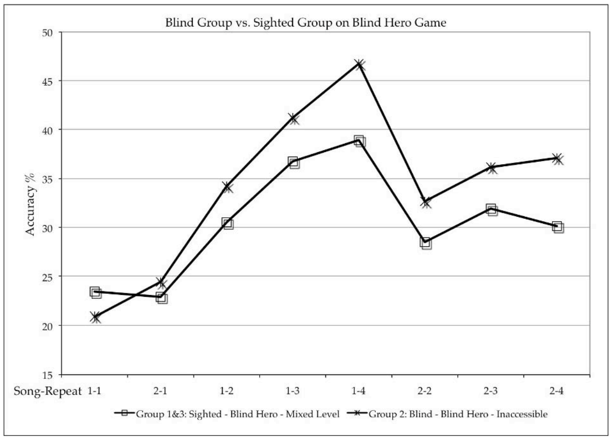

Figure 7: Blind people have better sense of touch?

brain does get too trained to react on things you touch on a day-to-day bases". Without being able to visualize, a blind person learns his or her surroundings by touching objects actively, and performs reading by touching the braille. Their brain has to constantly build bridges from retrieving feeling signals to sending a correct response signal to the right body part. From sensing motor vibrations to taking immediate action on the correct button, blind people practice this sort of behavior in their everyday lives. Sighted people are trained to visualize-then-act in daily life, while feel-then-act is not as common. Therefore, maybe it is the practice of feel-then-act that makes visually impaired players perform better than sighted groups. Nevertheless our study was relatively small with only 3 non-sighted players. To verify that blind players have a greater sense of touch, the experiment needs to be repeated on a larger scale to make these claims generalizable.

6. CONCLUSION

This paper presents a blind accessible version of a popular guitar playing game, called Blind Hero. We use the strategy of replacing stimuli as a tactic to make games accessible. We developed a haptic glove which translates visual stimuli into haptic stimuli. A study was conducted with Blind Hero involving sighted and non-sighted players, as well as performance measurements and comparison on whether players get a similar game playing experience as when they play Guitar Hero.

Our haptic glove can successfully translate visual stimuli into haptic stimuli despite having to compromise some elements of gameplay. Except for these compromises, all participants considered playing Blind Hero as a fun and enjoyable experience. Replacing stimuli may work to make games accessible but inevitably compromises have to be made. When making these compromises one should be careful not to jeopardize overall gameplay. We hope Blind Hero may serve as an example to the game industry on how to make music/rhythm games accessible to the blind.

Making games accessible using the strategy of replacing stimuli and other strategies, can improve the quality of life of many disabled individuals who feel left out, as the majority of the games are not accessible to them.

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