Rock Vibe: Rock Band® Computer Games for People with No or Limited Vision

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ABSTRACT
This paper reports *Rock Vibe*, a modification performed on *Rock Band*® computer game to represent visual information using haptic and audio feedback to allow people with no or limited vision to enjoy the game. We modified the drumming activity of *Rock Band*® by providing users with vibrations on upper and lower arms to represent the drumhead cues and on ankle to represent the kick drum cue. Auditory information is used to provide feedback on correct and timely hit (with various drumming sounds) or errors (with a click sound). Computer's standard speech synthesizer is used to read the menu, song title, instruction and score. A series of evaluations with people with various levels of visual impairment were performed at different stages of the system development. We found that users were able to master the system almost immediately, with some users making no error halfway through the first song.

Categories and Subject Descriptors
H.5.2 [**User interfaces**]: Auditory (non-speech) feedback, Haptic I/O

General Terms
Performance, Experimentation, Human Factors, Verification.

Keywords
Haptic, visual impairment, blindness, computer games, multiplayer game.

1. INTRODUCTION
Computer games have increased dramatically in popularity in recent years, and various statistics pointed out that they are no longer the exclusive playground of what used to be typically considered as computer gamers – adolescent males with no impairment [4]. Beyond a form of entertainment, games and play in general are important for developing, learning and practicing different skills, and with the advances of social and multiplayer games, as a means to connect with other people.

For people with sensory impairments, the advances in assistive systems can now offer computer games accessibility features of varying sophistication levels to compensate for those impairments (see, for example, PowerUp, a multi-player virtual world educational game with a broad set of built-in accessibility features [8] and UA-Chess, a Web-based chess that can be concurrently played by people with different abilities and preferences, including people with disabilities [3]). Most recently (and the study that is the closest to the study we report here) is Blind Hero, a modification to the popular Guitar Hero computer games for people with visual impairment through the use of a glove that transforms visual information into haptic feedback using small pager motors attached to the tip of each finger [11]. However, there is still few of such initiatives, and computer games are still in large inaccessible for people with disabilities, especially those with limited or no vision as many of these games rely heavily on visual information.

This paper reports a modification performed on *Rock Band*®, a commercial and popular video game available for the Nintendo Wii, XBox 360, and PlayStation consoles and can be played either individually or with a maximum of three other people (see Figure 1 for an example of the multiplayer mode of Rock Band called *Band World Tour*). Players have the option to play along to songs using the Rock Band's own drum kit or guitar, or to sing along by using a microphone. To play the game, players must watch the screen for visual cues telling them what to do and when. Upon correct and timely action, the correct musical phrases will be playing and a visual feedback will indicate that the players are in tune. When an incorrect action is performed, no musical phrase will be played and a warning will be displayed on the screen. At the end of game play, a score will be displayed on the screen.

Figure 1: Band World Tour, the multiplayer mode of Rock Band®

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As the aforementioned rules indicate, Rock Band relies heavily on visual information, and therefore it is very difficult for people with limited vision to play the game, especially due to the time sensitiveness of the game (i.e., if a player does not hit the instrument within a certain time window, the score will not increase). This study aims at making Rock Band more accessible for people with no or limited vision by translating fast changing visual information into haptic information, more specifically vibration, and slowly changing information into audio information. We chose to represent frequently changing visual information using haptic information rather than audio information as there was evidence that information representation using haptic information results in slightly more superior performance and preference than when audio information is used due blind persons' greater familiarity with haptic feedback, ranging from Braille devices to pedestrian crossing ramps [6]. In addition, haptic sense registers haptic information much faster than auditory sense does with sound. In this project, we only implemented the drumming activity of Rock Band. Our system is aptly called *Rock Vibe*.

2. RELATED WORK

A variety of factors had inspired some games companies and research groups to work on accessible computer games. Government legislation on software application could be a contributing factor. However, one factor that contributes to this provision is perhaps market demand. Surveys had revealed a shift in the demographics of computer gamers, mostly those that are not first-person shooter games. A survey on World of Warcraft, one of the most popular Massive Multiplayer Online Role Play games, indicates that 16% of their players are women, with average ages of 32.5 years old (SD = 10.0) for women and 28.0 years old (SD = 8.4) for male players, significantly above the stereotypical adolescent male age group [10].

Some of those accessibility initiatives focus on creating games specifically for people with disabilities. However, the majority of work seems to focus on providing accessibility add-ons to existing games, thereby allowing people with disabilities to participate in games commonly played by their non-disabled peers.

There are a number of works on making games accessible for people with visual impairment. Andersen described a 3D search and adventure game by modifying Quake[1] game engine source code to facilitate an audio user interface and provision of audio cues for player navigation [1]. The TIM (Tactile Interactive Multimedia) project makes use of tactile boards and move detectors as part of a flexible multimodal games interface designed for blind and visually impaired children through providing accessible description to the existing games and educational software [2]. Audio Space Invaders, as the name implies, is a modification to the traditional Space Invaders game, which combines audio and visual interfaces with force feedback joystick movement to produce a multi-modal game that can be played by both sighted and non-sighted users [7]. Finally, Shades of Doom is a self voicing version of the famous Doom[2] game, which allows players to navigate through the 3D environment using rich audio cues such as the sound of the wind, footstep echoes, and the noises made by machinery and equipment in the game environment, and cues when the player becomes disoriented or lost [9].

3. INITIAL DESIGN OF ROCK VIBE

The first step in the design of Rock Vibe was to decide on the haptic device to use as many special purpose haptic devices are costly (Phantom® Omni™ Force Feedback Joystick, considered one of the highest fidelity and most flexible devices on the market, costs around $2K, definitely not an option). It should be noted that Nintendo™ created a haptic add-on to their game controller called Rumble Pak [5], which provides force feedback while playing video games, such as vibration in when firing a weapon or receiving damage, to immerse players in the game. However, this device is still expensive (it costs around $30), could be difficult to find (it was initially released only in Japan) and is not compatible with some Nintendo™ DS games.

Through brainstorming sessions and online shopping, we came up with small, cheap, and durable vibrators similar to those found inside pagers. They cost under $2 each at retail cost. Although arguably an ideal system would be wireless, we could not find wireless vibrators at reasonable price. In addition, we used an Arduino microcontroller to control the vibrators – the controller board is unfortunately quite large and power hungry, which makes it difficult to turn into a wireless system (see Figure 2 for the size of the controller board). Arduino is an open-source electronics prototyping platform and can sense the environment by receiving input from a variety of sensors and can affect its surroundings by controlling lights, motors, and other actuators[3]. Appendix 1 shows the flowchart of Rock Vibe.

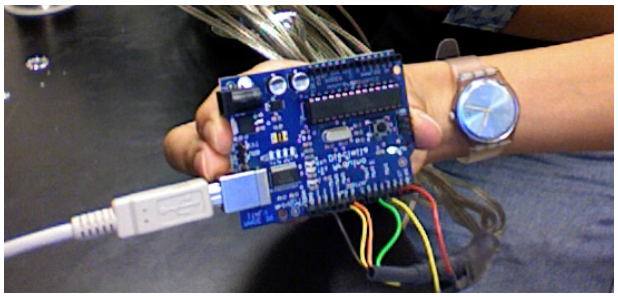

Figure 2: The microcontroller board of Rock Vibe

We then performed a brainstorming session on the placements of these vibrators, helped by a 13 years old blind girl. As the vibrators will not be wireless, one of the major challenges we faced was designing a comfortable and effective method of wearing them without getting entangled in wires. We found that the most effective way of presenting the visual cues is to place the

[1] Quake is a first-person shooter game, which since its release in 1996 had gained popularity, resulting in it being honoured in the 59th Annual Technology & Engineering Emmy Awards, 2008 for advancing the art form of user-modifiable games.

[2] Doom is one of the pioneering first-person shooter series in the video game industry (it was released in 1993 by the same company that produced Quake), introducing features such as 3D graphics, networked multiplayer game, and support for player-created expansions.

[3] http://www.arduino.cc/

drumhead straps on users' upper and lower arms - i.e., when a user has to hit the far left drum a vibration will be felt on the left upper arm, near left translated into left lower arm, etc. Another vibrator is placed on user's chosen ankle for the kick drum (see Figure 3).

We found that a simple Velcro strap was sufficient to deliver vibrating pulses to the player. The Velcro also allows the players to play without feeling restricted but at the same time does not have to worry about the straps getting loose. Rock Vibe informs players whether they have made a successful or unsuccessful hit with auditory cues. For example, when a correct hit is made, the player will hear a drumming sound (as in real life's drumming), and when an incorrect hit is made, a beep will be heard. At the end of a song, the player's score is vocalized via a speech synthesizer. We chose non-verbal cues for immediate feedback to minimize interruption that can break the player's attention, and only use speech for the feedback at the end of the song.

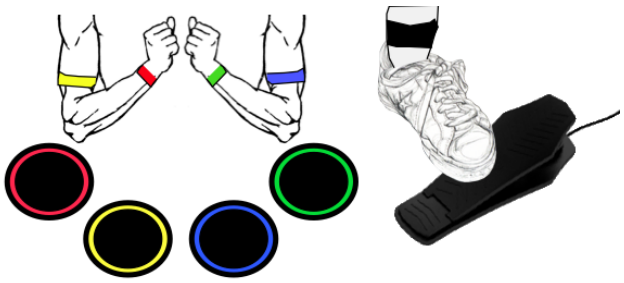

Figure 3: The mapping between vibrators and physical locations to activate

4. INITIAL INTERVIEWS

In parallel to the initial design of Rock Vibe, we conducted an interview to understand how people with no or limited vision play and perceive computer games. We recruited the interviewees from the Vista Center for the Blind and Visually Impaired, an organization that aims to empower individuals who are blind and visually impaired to embrace life to the fullest through providing various training, ranging from mobility and orientation to computer classes. Fifteen people with various degrees of visual impairment (including seven legally blind persons) participated (8 males and 7 females, most are Caucasians and a few are of Asian descent, with the ages ranging from 13 to 68 years old). Even though only 13 had some computer gaming experience, we still included the answers from the two participants with no gaming experience as they provided us with some insights from the points of view of non-gamer computer users with limited vision.

For those with gaming experience, the most common reason they decided to play computer games was because of boredom, the most common reasons not to play (either ever or temporarily) was lack of interest and/or time. The two non gamers also cited lack of interest and time as the main factor for not playing games, and one of them said "I have an aversion to anything to do with computer games. I have never played a computer game and have no desire to do so".

Next, we tested these participants on their haptic reaction times as to properly play Rock Band, the players had to respond to the cues within a certain time window, and we would like to ensure that haptic feedback can be perceived by our target users in timely manner. The participants were placed in a chair facing a one-inch button. The participants placed a Velcro strap on the wrist of their choice. During the test, the wrist strap provided randomly occurring vibrating pulses to the skin of the participants. The participants responded to the vibration by pressing the button. Reaction time is the latency between the pulse signal and the button actuation. Each participant was tested ten times. Our data shows that the time averages of the participants range from 0.92 s to 1.43 s (total average = 1.07 s), a sensible reaction time that would allow the participants, theoretically, to play some songs on Rock Band (albeit only the slower songs as the faster ones require reaction times closer to 0.5 s).

When we explained about Rock Vibe, nine people thought they could be successful playing the game, five weren't sure, and one thought she would be unsuccessful – she and another participant who was not sure were the only two that indicated that they would not be interested to try Rock Vibe. Some participants suggested that we have to calibrate the vibration intensity and the "time window" (i.e. to accommodate for people with slower reaction time) to each participant in the actual game implementation.

5. FOCUS GROUP DISCUSSIONS

When we started implementing the system, we realized that there are more complex issues that we had to consider beyond the real-time translation of the "hit" cues (the colored rectangles that appear on screen that alert the player to hit a certain drum at a certain time) into vibration pulses and the translation of the "score" (the glowing rectangles that tell the player whether or not the correct drumhead has been hit on time) into either a beep or a drumming sound. For players with no useful vision, all of the visual information, including the song title and level of difficulty, has to be represented using other modalities. To help us in the system design, we conducted a focus group consisting of us and two blind gamers that participated in the initial interviews. In this focus group we discussed about possible ways to present the various information, although we soon came into agreement that there was not much alternative we could do beyond presenting fast changing information, i.e., the drumbeats, using vibrations, and everything else using audio information.

One useful insight that we received from the focus group discussion, however, was a use case of how a typical user with no vision would use the system. We presented here the use cases that resulted from the discussion to provide an idea of how the system operates in its entirety (we did not include in this paper the use case's *alternative courses/extensions* – the cases when things do not happen as planned, such as when the system fails to voice out the menu or to vibrate).

Use Case

1. *The user attaches the Rock Vibe unit to the gaming console.*
2. *The user turns the Rock Vibe unit and the gaming console on.*
3. *Rock Vibe begins voicing the main menu and instructs the user on how to navigate the menu. User can press ESC to skip the instruction.* (Note: the ESC was a later edition suggested by our blind group member)
4. *The user sits down in front of the drum kit.*
5. *The user puts on the wearable vibrators.* (Note: this is when we realized that we need to provide some non-visual cue as to which strap goes where)

6. *The system vocalizes out the vibration intensity calibration screen.*
7. *The user chooses the intensity by pressing the up/down arrows to increase/decrease intensity for each vibrator.*
8. *The user begins navigating the menu and the system vocalizes which menu item is highlighted at the time.*
9. *The user chooses the number of players.*
10. *The system says the number of players as confirmation.*
11. *The user selects the level of difficulty she wants from Easy, Medium, Hard or Expert.*
12. *The system says the chosen level as confirmation.*
13. *The system vocalizes the song that is currently highlighted.*
14. *The user scrolls through the songs until she finds one that she likes. The system reads out the song titles as user travels through the song selection.*
15. *The user selects the song.*
16. *The system vocalizes the chosen song as confirmation.*
17. *Right before game starts, the Rock Vibe's vibrators vibrate to confirm that they are working properly.*
18. *The relevant vibrators then only vibrate to instruct the user on which drumhead to hit when.*
19. *The user hits the drumhead at the correct time and the system produces a drumming sound.*
20. *The user hits the drumhead at the wrong time and the system makes a beeping sound.*
21. *The user hits the wrong drumhead and the system makes a beeping sound.*
22. *The song finishes and the system vocalizes the score.*
23. *The system then vocalizes the menu that pops up at the end of the song.*

6. HEURISTICS EVALUATION

To ensure that we were on the right track, we performed a user evaluation with the high fidelity prototype of Rock Vibe. To provide context for evaluation, we asked six interviewees with visual impairment (none were legally blind) that had not participated in the focus group discussions to use the Rock Vibe. We had the following setup: a drumming sound if the player hit the correct drum on time, a beep if an incorrect drum was hit, 500 ms to react after vibration to increment the score, and the final score was vocalized by the computer's speech synthesizer. Each participant had ten trials, and we informed them that this was not a measure of their performance; rather these trials were intended to give them some experience of how the system works. Each participant performed the trials independently. Figure 4 shows an example of the setup of this evaluation (we intentionally removed the person's identity from the picture).

After this session, we interviewed the participants using Nielsen's heuristics as a guide, modified as necessary. The following are the results of the interviews:

1. Visibility of System Status
   a. *Are users getting meaningful feedback when they are hitting the correct drum*? YES, they hear the drumming sound.
   b. *Are users getting meaningful feedback when they are hitting the incorrect drum*? YES, they hear a loud and long-lasting beep. However, some participants complained about how annoying the beeps were, especially when they were just getting a grasp of the game and made many errors.
   c. *Are users getting meaningful feedback when they have finished playing a level*? YES, the score is vocalized via computer's speech synthesizer at end of the level. It sounds a bit metallic, but understandable.

Figure 4: The setup of Rock Vibe for the heuristics evaluation

2. User Control and Freedom
   a. *Do the users have the option to place the vibrators where they want*? YES and NO, they are allowed to put the straps slightly higher or lower on their arms but they cannot put the arm bands in any other parts of the body due to the strap length and the fact that there should be four distinct locations to correspond to the four drumheads. The ankle strap has more freedom as user can place it in either foot/leg, but the length of the strap prevents it from being placed on, say, the waist (this was a request from one of the participants who said that he has higher sensitivity on his waist than on his ankle).
   b. *Do the users have the option to adjust the vibration intensity*? YES, and everybody appreciated this, especially as they prefer to have stronger vibration for the upper arms and ankle.
3. Consistency and Standard
   a. *Does the system have consistent feel to it*? YES, once the vibration intensity is calibrated, the vibration is always constant in its intensity, and except when the straps got loose, the vibrations always come from the same places on their bodies. The beeps, drumming sound and voice synthesizer also provide consistent feel to the system.
4. Recognition Rather than Recall
   a. *Does the system facilitate easy recognition rather than asking users to remember*? YES and NO, when the participants were still learning about the game, heavy recall is required to correlate between the body part that receives vibrating information and the drumhead to hit. After the players got used to the system, the experience moved into automatic recognition process rather than recall. However, some participants complained that the mapping between the arm/wrist straps and drumheads is not intuitive, and therefore is not easy to remember. They suggested that a more intuitive mapping is to swap the

mapping of the upper and left arm straps to the drumheads, essentially left wrist = yellow drum, upper right arm = red drum, right wrist = blue drum, and upper left arm = green drum (please refer to Figure 3 for the mapping).

5. Aesthetic and Minimalist Design
   a. *Is the game free from irrelevant, unnecessary and distracting information?* YES, the participants were unanimous that the system provides sufficient feedback in timely manner and no distracting or unnecessary information was produced by the system (although one participant indicated that the beep could be distracting, in one case she made the second mistake because she "jumped" when she heard the beep from the first mistake).
6. Match between system and the real world
   a. *Does the system use concepts that are familiar to the users?* YES, the drumming sound for correct hit and beep for incorrect hit are familiar concepts. Some participants even indicated that the speech synthesizer is a familiar concept to them. However, some participants suggested that the system should produce different sounds when different drumheads are hit to make it more similar to real-life drumming activity.
7. Error prevention
   a. *Does the system eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action?* YES and NO, the system voices out the selected song title and level of difficulty to ensure that the participants had chosen the intended song and difficulty level. However, the system does not have error prevention for wrong drumhead being hit.
8. Help users recognize, diagnose, and recover from errors
   a. *Does the system provide error messages to indicate the type of error user does and solution to remedy the error?* NO, other than providing a beeping sound to indicate that the user has not hit the correct drumhead in time, the error message is not very informative (i.e., the user does not know whether the error was due to hitting the correct drumhead late or hitting the wrong drumhead, or both).
9. Flexibility and efficiency of use
   a. *Does the system provide accelerator for expert users?* YES, the system provides an ESC function to skip the instruction. The Rock Band game itself provides various levels of difficulty for novice and expert players.
   b. *Are novice users given enough support?* NO, some users complained that the 500 ms threshold was too short, and for novices, hearing beep after beep could discourage them from continuing to play the game.
10. Help and documentation
   a. *Does the system provide help and documentation easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large?* NO, there are only very basic instruction and menu, but unfortunately fixing this problem is beyond the scope of this project as the help and documentation are provided by Rock Band and we just implemented the voicing out function of these help and documentation.

7. SYSTEM REVISION

To address the problems highlighted in the heuristics evaluation, we performed a brainstorming session among us and made the following changes:

- The beeping sound is now changed into a clicking sound – this still indicates that the user has made an error but in using slightly less aggressive sound.
- The correct hit sounds now vary depending on which drumhead and kick drum the user activates: red drum now makes a snare drum sound, yellow drum makes a hi-hat sound, blue drum makes the sound of a tom-tom, green drum makes a crash cymbal sound, and kick drum sounds like a kick drum.
- We swapped the mapping of the drumhead to the arm/wrist straps as suggested by the participants.

Unfortunately we could not implement the longer reaction time window as when this system will be used for real songs, the window will be decided by the pace of the songs. The only thing that we could suggest to players in the future is to choose slow songs if they have slow reaction times.

8. SYSTEM EVALUATION

For the final user testing of Rock Vibe, we recruited participants with various levels of visual impairments (one is totally blind, two could only detect some light and sharp contrasts, and one user has central vision loss) from the Disability Resource Center of the University of California Santa Cruz and from the visual impairment center of the City of Santa Cruz Board of Education. Seven people agreed to participate, ranging in ages from 9 to 37 years old. Three said they played computer games frequently, three said they don't play computer games, and one used to play computer games but doesn't anymore as his sight become worse. None had played Rock Band before.

To account for the drumming experience variability, we asked if the participants play any musical instruments. Six of the participants have played piano, four of whom said they have played only a little, and two of whom have played it for six years or more. One of the users played the trumpet for three years and also used to be a bassist in a band. Only one user said that they had "played around with drums." One user said that they had two years of violin when they were a child and another user just started playing the violin five weeks prior to the study.

For this evaluation, we were interested in hearing the participants' comments as well as in understanding whether it was possible for people with limited or no vision to play Rock Vibe following the "normal" rhythm of popular songs. Two songs were used in this evaluation: Weezer's "Say it Ain't So" and Yeah, Yeah, Yeah's "Maps." Both songs are around the same length (around 4 minutes) and have a similar number of drumbeats per minute. We asked the participants whether they had heard these two songs before (to remove variability in song familiarity which can lead to anticipation of the next drumbeat) and none of the participants had heard these songs before. The presentation order of these two songs was balanced as much as we could.

A calibration session, in which the participants chose their own vibration intensity and strap placements, and a practice session in which the participant was given a simple song ("Mary had a little lamb"), preceded the real evaluation. The participants were

allowed to ask for more practice if they felt they still could not remember the mapping, which in this case a backup song would be used. The participants were informed that they were only allowed to take a break between songs. However, we had to stop one participant (after pausing the song) as she started using her hands, instead of the drumsticks, to hit the drumheads (as we were afraid she might break the drumhead, and we could not have compared her data to others').

Figure 5 shows the number of errors by the song minutes (we just categorized the errors by either the first or the second song the participants heard as we considered that those two songs are of similar genre, pace and complexity). As this figure shows, there is a remarkable decline in the number of errors made by minutes. Some participants even made no error halfway through the first song. We noticed that the errors are a combination of late hit and hitting the wrong drumhead at the beginning of the songs, but toward the end of the songs most errors were late hits rather than hitting the wrong drumhead.

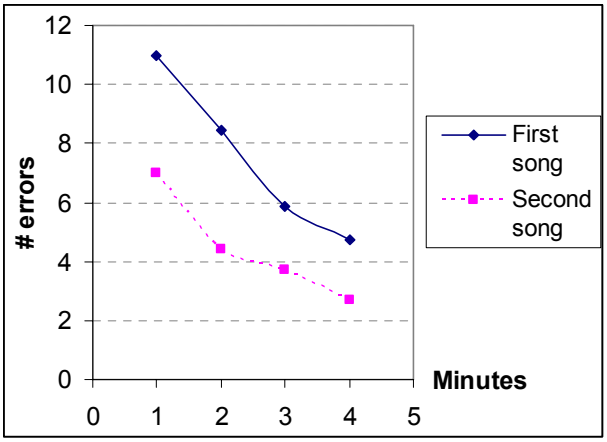

Figure 5: The number of errors by minute

We also interviewed the participants after the session to gather their comments about the game. In general the participants enjoyed the game and felt that it was not very difficult or frustrating to learn. They did not feel that the clicking sound was intimidating or annoying (which was a good sign of improvement compared to when the beeping sound was used, although some complained that the click was too loud). The participants did not feel that the songs were too fast. Two suggested that they should be allowed to play using their hands rather than drumsticks as they had much better sense of where the drums are located using their hands. Some other participants also complained that the fact that the straps had to be located close to each other causes problems in songs with fast beat as, for example, when the upper left arm vibrates followed by the left wrist in fast succession, they had to think which one was first, causing either wrong or late hit. If it would have been possible to locate some straps on the shoulder, it would give more physical separation and less confusion. Finally, all of the participants indicated that they would recommend this game to their friends with visual impairment (although some thought that the cost of Rock Band, which was $60 without the peripheral instruments or $100-140 as a package with the drum, guitar or microphone, was too high for many people with visual impairment, especially as the player must have one of the following consoles: XBox 360, Nintendo Wii, PlayStation 2, or PlayStation 3. They range in cost anywhere from $129-400). In addition, songs that are not included with the software must be purchased for around $30-40.

9. DISCUSSION AND CONCLUSION

This paper reports the modification to a popular musical computer game to make it more accessible to people with no or limited vision. This was achieved through representing visual information with either vibration or audio information. Through a series of user involvement throughout the different stages of system development, we arrived at a system that we found can be reasonably quickly learned by people who had never played the game before, albeit still not error free for everybody.

While because of the costs associated with Rock Band and its peripheral instruments this project would probably fail to reach a large number of people with no or limited vision, we learned a number of lessons from the project (beyond the fact that involving users throughout the system development had resulted in what we felt were a system that is both usable and accessible for our target user group):

1. There is a need to balance between warning users of errors and using information medium that is not perceived as aggressive or annoying, as it can affect user performance (as in the case of beeping sound).
2. There is a greater need for user customization when non-visual information is involved than when only visual cues and information are needed (as in the case of vibration intensity, strap placements, and the loudness of audio information – especially the warning sound).
3. It seems that mapping haptic feedbacks on multiple body parts to motor movements in various spatial locations is reasonably easy to learn and remember (at the beginning of the project, we were worried that it would be difficult for people to learn to map between various vibrating body parts to the spatial locations of the drumheads, a concern that was unfounded).

Undoubtedly, there are still disadvantages that people with no or limited vision have when playing computer games that are visually oriented. For example, sighted player can anticipate his/her next move as visual cues for the next beats travel down the screen, something that would require quite a complex design when presenting the information in non-visual forms as both audio and haptic information tend to be serial in nature, unlike visual information that can be processed in parallel. Interestingly, actually one participant of the final evaluation provided an idea of how to present future information. He suggested that it might be worth testing create wearable vibrating strips starting from the shoulder, where the vibrations travel down the specific part of the body until they hit the point that alerts the player that it is time to react (similar to the way the visual cues travel down the screen). We did not implement this due to system complexity. In addition, we felt that this might distract the users from the main task.

Sighted players also have an advantage in term of information redundancy. The Rock Band's drumheads are color coded, and the same color coding is used for the visual cues. Therefore, sighted users receive spatial cues as well as color cues, while non-sighted users do not receive the latter cues.

While there are still disadvantages that non-sighted players have compared to their sighted peers, this project is hopefully the first

step in the right direction of creating a musical computer game for people with no or limited vision. There is plenty of work that still needs to be done to make this system more enjoyable for this user group. We have not tested the multiplayer function of Rock Vibe, which would be a natural future step, as it would allow this user group to take full advantage of social games for connecting with other people, sighted and non-sighted.

We should probably look at more flexible strap placements, especially as implementing this idea is as simple as providing longer Velcro straps. This is especially important for those who lost sensitivity on various parts of their bodies due to aging. And finally, the issue of reaction time window kept arising. This is understandable as different people, especially those who lost their sight due to aging, cannot be expected to react as fast as their younger counterparts, and therefore we need of thinking of a way to adjust for slower reaction time. We attempted this by slowing the testing song, but it made the song to sound unnatural. Hence, other than our original idea of using slow songs for those with slow reaction times (we argued that many older persons would probably enjoy slower songs than those in other age groups so we hope that this would not pose huge problem for the older user group), we have not found a way to adjust for this reaction time variation.

While the main aim of Rock Vibe is to provide a means for people with no or limited vision to enjoy this game, we all actually enjoyed the non-visual mode of Rock Band. Many of us felt that the screen backdrop is visually distracting. Some of us were often distracted by the avatars playing the instruments (see Figure 6 for the single player mode of Rock Band to view how prominent the avatar is) and lost track of the visual cues we were supposed to be following. Certainly this finding is anecdotal and would require user testing (as we all were involved throughout the system development and were therefore trained to use the haptic cues), but this opens the possibility of offering Rock Vibe as a universal game, the same way UA-Chess [3] or Audio Space Invaders [10] are intended to be.

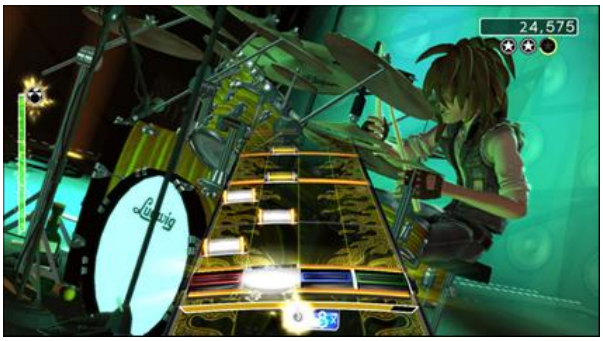

Figure 6: The avatar of Rock Band

10. ACKNOWLEDGMENTS

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APPENDIX 1: ROCK VIBE'S FLOWCHART