Audio-Based Puzzle Gaming for Blind People

Jaime Carvalho, Tiago Guerreiro, Luis Duarte, Luis Carriço
LaSIGE / University of Lisbon
Campo Grande Edificio C6 Piso 3, 1749-016, Lisboa
jcarvalho@lasige.di.fc.ul.pt, tjvg@di.fc.ul.pt, lduarte@lasige.di.fc.ul.pt, lmc@di.fc.ul.pt

Abstract. Mobile devices provide opportunities beyond communication and productivity. Particularly, they are increasingly used to entertain the nomadic user. Mobile casual games are increasingly popular as their simplicity, lack of commitment required and neglect for particular special skills goes hand-in-hand with the reduced and partitioned time spans associated with daily contexts. Gaming possibilities for blind people are scarce. The extra demands imposed by mobile interfaces and contexts augments this exclusion. Given the paucity of mobile games for blind people along with the recognized benefits of such gaming experiences, we present an audio-based puzzle game for blind people. In this paper, we depict the iterative (participatory) design of the game along with a preliminary evaluation with 13 blind participants. Results show that the game is fun and challenging and suggest that playable counterparts of visual-based games are feasible even in restrictive contexts as is the mobile one.

Keywords: Mobile, Puzzle Games, Blind, Audio.

1 Introduction

Mobile casual games are increasingly popular. The multitude of game types along with the ability to play these games in a partitioned game setting enables their use in nomadic daily contexts. Popular situations are while waiting for or while riding public transit but they can be played virtually anywhere. However, in a mobile context, every once in a while people are situationally impaired [5]. These scenarios as well as in the case of individual disabilities give space for different interaction modalities. These are likely to be able to cope with a wider range of abilities and scenarios thus promoting inclusion (e.g. [6]). The use of a higher number of modalities can increase the vocabulary of symbols available to the user leading to increased accessibility [4]. Still, accessible mobile gaming options are scarce. We focus on blind people where a lack of mobile games is patent.

There have been some efforts to deploy videogames for blind people in non-mobile contexts particularly by designing games that fit both sighted and non-sighted audiences [6]. More recently, other focus has been in promoting physical activity through games [3]. Another area of interest is music and rhythm, because they are particularly suitable for blind people, perfectly capable of perceiving audio signals. Some examples are a game that allows blind people to play Guitar Hero [7] or a game that allows the creation and re-creation of different beats through different sound pieces [2]. This is one of the few examples of games applied in a mobile context.

In this paper, we present audio puzzle games, an interactive way of playing with music by rebuilding a song, just like the original image jigsaw puzzle, broken into pieces which are by turn randomly shuffled. The audio mode design followed a participatory approach starting from a version similar to the visual one, but around music instead of images. We evaluated 13 blind people using the proposed game application with three different songs randomly distributed.

2 The Audio Puzzle Game

A game application has been developed for Android platforms which allows users to solve musical puzzles. The market available solutions are still rooted on the original concept, solving visual jigsaw puzzles. As such, we envisioned a musical puzzle game without any visual feedback, where the main goal is to reconstruct a fragmented song by putting each individual segment in the correct order. This audio puzzle mode has not been so thoroughly explored in both research and videogame industry.
Our concept is based on the traditional cardboard puzzles games, as well as an application previously developed [1]. In this first application, the puzzle is square shaped containing x^2 pieces, where x is the numerical representation of each side of the square. The pieces are randomly placed on a strip below the puzzle; the user can drag and drop them into the correct position in order to solve the puzzle. In this application it is possible to solve two different kinds of puzzles, visual and audio, both with a visual component (Figure 1). The same way that an image is cut into equal parts, we apply this concept to music. The basic idea is to split one song into many pieces of the same size, shuffling them, and allowing the user to re-create the original song.

Our aim was to develop an application that allows playing the same audio puzzle concept, but without the visual component. This allows blind or those with situationally blind to play.

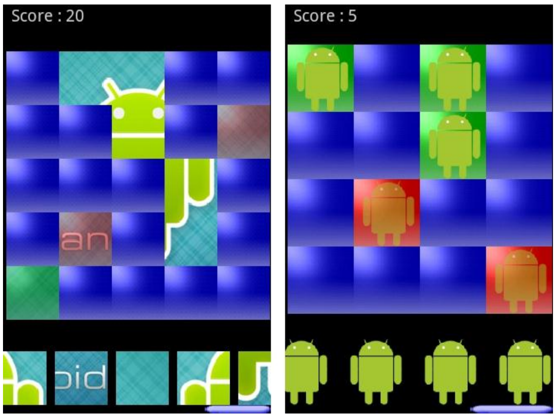

Figure 1 – Visual puzzle mode (left) and Audio puzzle mode (right) interfaces.

2.1 Participatory Design of the Audio Mode

Our research team for the development of this specific application was complemented by two blind people, one computer science student and a psychologist. This participatory design approach enabled us to iteratively develop our prototypes taking in consideration both their personal difficulties and opinions. Interface challenges were discussed and improved accordingly to feedback received in hands-on meetings. These enabled us to perceive errors, improvements and to try interface variations. Particular changes to be stressed rely on the addition of text to speech and sounds as cues for particularly defined actions. Sounds complemented haptic feedback to deal with possible situationally impairments and/or maximize perception. Also, onscreen positions and touch gesture recognition parameters (timeout, distance and angle) were parameterized to improve accuracy. Sessions with different puzzle sizes were performed to assess acceptable parameterization for the usability evaluation sessions.

2.2 The Audio Mode

The main change in this mode is the removal of visual feedback. The game playability was transformed in a simple combination of finger movements (e.g. slide to move pieces and taps to require help) and audio feedback. The screen, although with no visual feedback, is equally divided in three zones. The target strip is placed in the top area. The middle area contains the currently selected piece, while the bottom area is a container for the complete song being played. By double tapping the middle area, the user can listen to the current piece. By sliding to the right or left, the next piece is selected, working like a strip of unplaced pieces (song segments). By sliding up, the user tries to place the piece in the target strip. Different feedback sounds and vibration patterns are associated with success and failure in placing a piece. No manipulation of the target strip is possible turning the placement of the pieces as sequential thus following the natural order of the song being played (the first piece to be placed must be the first segment of the song and so on). Exception is made for double tapping the target area (top) which plays the completed part of the puzzle.

The puzzle can have any x pieces as long as x^2 does not exceed the maximum length size of the selected music. The pieces are randomly distributed on the middle strip. A speech synthesizer was used to read to the user the total number of pieces to be solved, the number of pieces completed so far and the final player statistics. A simple score system was also developed based on the number of correct attempts, adding three points, and incorrect attempts, subtracting one point. This scoring system is meant only to motivate the players allowing better results and performances.

3 Evaluation

Preliminary sessions with two blind people suggested that the audio puzzle game was fun and that the users were able to use it effectively. However, these users accompanied through all the design process and had increasing experience with the concept. Further, they represent a motivated and differentiated set of the target population (highly educated). To assess how the game performs regarding fun, difficulty, playability and challenge we performed an evaluation with blind people from broader backgrounds.

3.1 Participants

We recruited 13 blind people (9 males and 4 females) from a formation centre for blind people with ages comprehended between 26 and 61 years old (M=47.9, SD=10.26). Three participants stated to often play casual games on their computers but not so often (or never) on their phones. Also, all participants were familiar with puzzles but they did not play them. Only one participant, the youngest one, had contact with a touch screen mobile device. Five participants acknowledged to have had some type of musical formation in the past and this showed to be significantly positively correlated with Age (Spearman, rho=.612, $p<.05$).

3.2 Apparatus

We used the Samsung Galaxy Mini touch screen device, which runs Android operating systems. The device was previously loaded with the latest version of the Audio Puzzle Game. This was instrumented to manage and capture the session with each participant. Instructions were provided via text-to-speech. Pico TTS was used as the speech synthesizer.

3.3 Procedure

The experimental period started with a pre-experiment interview to characterize the subjects (e.g. age, gender, experience with modern smartphones, music theory knowledge, etc.). With the help of the experimenter, participants started by learning the interface and were able to perform a 4-pieces training puzzle. All doubts and questions were answered during these tutorial sessions which could comprise more than a training puzzle (within a maximum timespan of 15 minutes)

The participants were asked to solve 9-piece song puzzles with three randomized songs. The pieces have a time period of two seconds. The songs selected were: Beethoven's 5th Symphony, a more instrumental song, Ben Harper's "Diamond's on the Inside", and a national slow song with lyrics (Rui Veloso's "Porto Sentido"). The order of the songs was randomized to counteract order effects.

All trials were video recorded and all interactions with the application were logged for further analysis. A post-questionnaire was employed as a 5-point Likert scale to assess the users' opinions.

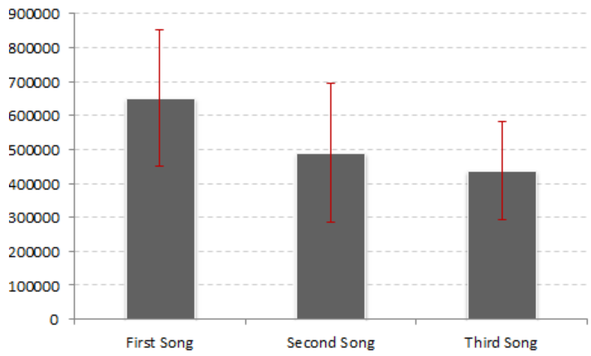

Figure 2 – Time (in milliseconds) taken to accomplish each of the puzzles (independently from the song). Error bars denote 95% confidence intervals.

3.4 Design and Analysis

The experiment was set-up with a within-subjects design where each participant performed all three puzzles. Each puzzle was composed of 9 pieces (music segments). Dependent variables were the Time to complete the puzzle, the number of Placing Attempts, and the number of Individual Helps and General Helps required during a trial. Given the non-normality of the data (according to Shapiro-Wilk normality tests), non-parametric tests were used in the analysis. Friedman tests were used to compare between trials and post-hoc Wilcoxon Signed Rank tests with Bonferroni corrections were applied for multiple pairwise comparisons.

3.5 Results

Our main goal was to assess if a audio-based version of the puzzle concept for blind people was feasible. Indeed, most participants stated to be ready for a harder puzzle after around 5 minutes of training. None required the whole training time (15 minutes) but still, four participants played the 4-piece training puzzle twice before they could say they were comfortable with it and the evaluation monitor could say that all interface elements were understood.

Figure 2 presents the average time spent by the participants to accomplish the three puzzle trials. A significant effect of Puzzle Trial was found on Time (Friedman test, $x^2(2)=6.5$, $p<.05$) with post-hoc tests revealing that participants were slower in the first contact (M=651082 ms [10.9 minutes] , SD=369480 ms) with the application (Wilcoxon, $p<.05$) than the second (M=490172 ms [8.2 minutes], SD= 375467 ms) and third (M=437665 ms [7.3 minutes] , SD= 267450) trials. There was no significant effect of *Puzzle Trial* on *Placing Attempts*, *General Helps* and *Individual Helps* suggesting that users are faster but they maintain similar playing patterns. The chart in Figure 2 shows high error bars which mean high standard deviations which can by turn be explained by individual differences in ability within the target population. However, no correlations were found between the time taken to finish the tasks and users' age or expertise with puzzles, technology or having musical formation.

Puzzle Song showed to have no effect on Time, Placing Attempts, Individual Helps or General Helps. This means that users took in average the same time (and had similar playing behavior) with both instrumental and lyric-rich songs. Also, no correlations were found between individual attributes and playing behaviors. After each puzzle, the participants were asked about their familiarity with the songs (3-point Likert scale). These ratings also showed no correlations with the playing patterns and strategies.

Figure 3 presents the number of Placing Attempts and Individual Helps for each puzzle piece along with the audio wave form of Beethoven's 5th Symphony. In this music, the second piece was the most problematic since it blends musically with the fourth piece. Also, something to take note is the great musical similarity between pieces five and six. The first and third pieces also have similar sounds but with different music notes. The rest of the pieces are quite distinguishable. Individual helps are not commonly used (total of 57), but the total number of general helps for this music is one hundred (100), spread throughout the music.

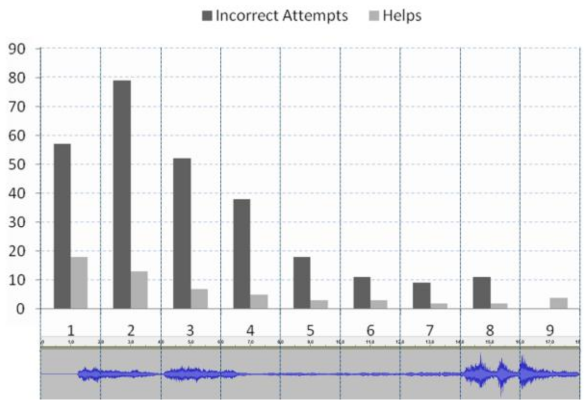

Figure 3 – Overall incorrect Placing Attempts and Individual Helps along with the sound waveform of each piece (Beethoven 5th Symphony).

The second music, a song with English lyrics, was Ben Harper's "Diamonds on the Inside". Most segments of this song are lyric-based. Although the waveform is indistinctable, the lyrics are very important in the disambiguation. Only two pieces, the first and the seventh, are purely instrumental. It was noticeable again the lack of use of the individual helps (62), in comparison with general helps (144). The low awareness of this music is more notorious than the previous, since it suggests more errors throughout the all music; greater number of errors in the early pieces (1, 2 and 3), and still relevant mistakes in the following (4, 5, 6 and 7).

In the last music, we chose a song with Portuguese lyrics in order to discover whether it was easier to solve. This particular song has three pieces of pure instrumental sound, the first, the fifth and the eighth, all different from each other. And once again, all the other pieces have lyrics, which may facilitate distinguishing the specific pieces. It is observable the relative difference of failed attempts (smaller than the other two songs). The total number of incorrect attempts is the lowest of the three songs along with the total number of individual helps (49); the total number of general helps (121) is higher than in the Beethoven's but smaller than Ben Harper's song. This suggests that knowledge of the music in hands makes it easy to resolve, enabling less failed attempts and reducing the usage of helps (this results were not statistically significant tough).

3.5.1 Case studies

In this section we will give special attention to two particular interesting cases. The first highlight belongs to the best performance in all aspects, P13, with 26 years old, which is the only participant with some experience with tactile devices. She presents a total average resolution time of the puzzles of 216 seconds, (1st: 370 seconds; 2nd and 3rd: about 140 seconds). The average number of *Placing Attempts* is 13 which is good given that the minimum amount of movements is 9. This participant only used 2 general helps per game, and hardly used the individual ones. The other user is P11, also for its good performance but also for his age, a 60 year old male. His average completion time was of 325 seconds. He had more difficulty in the classical music, taking 619 seconds. In the other two (lyric-rich) the times were quite constant and of about 178 seconds. The total number of movements was in line with the previous results, worst in the classical music, with 40 moves, while the other two were constant (21 for each). As to general helps, P11 used around 2 per game, and the individual helps were strongly used on the 5th Symphony (8). In sum, users with marked different profiles and backgrounds were able to play the game and find it challenging and fun. Even an older participant was able to enjoy the game in a first contact with puzzle games and touch devices, and show improvements during gameplay.

3.5.2 Users' Opinions

In the overall, the participants enjoyed playing the game and felt challenged by it. As with performance, we did not notice particular disinterest from older blind people: they also stated that games for blind people are coming short and are welcome.

Figure 4 – Users' ratings (5-point Likert scale). Central tendency is presented with Median values while error bars denote inter-quartile ranges.

Figure 4 shows how the participants rated the four statements concerning the Fun, Playability, Challenge and Difficult of the game. Results show that participants were consistent in positively evaluating the application with low rating dispersion. They thought the game was fun, playable and particularly, challenging. This is very relevant as they were neutral about difficulty. This difference between challenge and difficulty shows that they did not see the game as inaccessible but as something they could and keep engaged with. Most participants stated to have felt insecure, mostly in the beginning, about the interaction areas on the screen and the primitives performed (e.g., flicking gestures). This lack of confidence can explain why the participants were slower in the first contacts with the application but had similar number of interactions. Participants pointed out that the game would be interesting to make time and to relax. Several participants said that the application was very interesting to play with at bus stops, while riding public transit or while at home. Most participants were thrilled with the ability to play with any music on their phones and tried songs of their own.

4 Conclusions

By deploying games that resort to different modalities and interaction channels we intend to foster inclusion and increase the possible usage scenarios. In particular, by providing mobile games that neglect all visual feedback we are automatically including all users unable to receive such information. This includes blind people but also those that are situationally blind. In a casual gaming scenario, it is plausible to encounter situations where looking at the screen may not be advisable or possible (e.g. screen glare or pocket interaction).Results show that the audio mode is considered as challenging, playable and fun by blind people. Also, a detailed view on the results presented the audio-based puzzle game as an application accessible for a diverse set of blind users (different backgrounds and abilities).

In the future, we plan to pursue different versions of the same concept, e.g. haptic puzzle games, and to apply similar participatory design approaches with other game breeds.

5 References

[1] Jaime Carvalho, Luís Duarte and Luís Carriço. 2012. Puzzle Games: Player Strategies across Different Interaction Modalities. Fun and Games 2012. To Appear.

[2] Joy Kim and Jonathan Ricaurte. 2011. TapBeats: accessible and mobile casual gaming. Proc. ASSETS '11, pp. 285-286.

[3] Tony Morelli, John Foley, and Eelke Folmer. 2010. Vi-bowling: a tactile spatial exergame for individuals with visual impairments. Proc.of ASSETS '10, pp. 179-186.

[4] Oakley, I., Brewster, S. A., and Gray, P. D.: Solving multi-target haptic problems in menu interaction. CHI'01, Seattle, USA, pp. 357-358.

[5] Andrew Sears, Min Lin, Julie Jacko, and Yan Xiao. When computers Fade...Pervasive computing and Situationally-Induced impairments and disabilities. In C. Stephanidis, editor, Human-Computer Interaction: Theory and Practice (Part II)., pages 1298–1302. Lawrence Erlbaum Associates, Hillsdale, 2003.

[6] Luis Valente, Clarisse Sieckenius de Souza, and Bruno Feijó. 2008. An exploratory study on non-visual mobile phone interfaces for games. Proc. of the VIII Brazilian Symposium on Human Factors in Computing Systems, Porto Alegre, Brazil, Brazil, pp. 31-39.

[7] Bei Yuan and Eelke Folmer. 2008. Blind hero: enabling guitar hero for the visually impaired. In Proc. of Assets '08. ACM, New York, NY, USA, pp. 169-176.