MASTERBLIND - TESTING THE USABILITY OF AUDITORY FEEDBACK IN A COMPUTER GAME FOR BLIND PEOPLE

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ABSTRACT

The present study presents an adaptation of the Mastermind board game for blind users - Masterblind. Given the focus on visual information in the original game, the game mechanics were simplified and auditory feedback introduced. The research object was to understand what kind of sounds would work better to help blind people play the game. Three versions were presented to the subjects - pentatonic notes, animal sounds and vowels - to help users recall previous steps in the game. The main hypothesis predicted that blind users would consciously benefit from the auditory feedback provided. The second hypothesis predicted that users would benefit less from the feedback that doesn't provide semantic information. The results were congruent with the hypothesis, although revealing an important role for spatial awareness. Masterblind can be an usable, enjoyable and a challenging experience for blind users as long as it provides semantically significant feedback.

KEYWORDS

User Experience Design; User and Cognitive models; Interface Design Games/Play

1. INTRODUCTION

A computer game adaptation of the board game Mastermind [1] was designed and prototyped to address the difficulties in visual interfaces blind users may have - Masterblind. There are several variations of the game, but the original concept is based on having a player generating/choosing a secret key of four coloured pieces out of a set of eight different colours - with or without repetitions of the same colour - while the other player, in several rounds, tries to guess the correct secret key previously generated. At each round the second player tests a combination of coloured pieces and according to the feedback given by the first player, he tries to deduce the key by presenting new combinations. The feedback provided by the first player consists in informing the second player of how many pieces are the correct colours in the correct position, and how many pieces are the correct colours but in the wrong position. The game ends when the key is discovered or the number of maximum attempts is reached. The main design problem was to understand how the original concept of Mastermind that relies so much on visual information could be adapted to a computer game for blind users, without any visual output. Three main aspects of the role of visual information were identified and hypothesized to have a significant role on the mechanics of the original game: 1) the distinctive capacity for the user to clearly identify each element of the secret key; 2) accurate but at the same time, vague feedback that provides just enough information for the player to derive the correct solution without losing the puzzling element that is essential for these kind of games; 3) accessibility of information about the previous

plays to minimize repeated answers in the following attempts. To address these aspects, several design choices were made. Following the direction of S. Targett et al. [2] using audio feedback and simplifying the game mechanics has driven those choices. First, to keep the balance between enjoyability and the challenge that one derives from a puzzle game such as this one, the number of possible elements for the secret keys were reduced from eight to only four elements and repetitions were excluded. This way, due to the secret key also having only four elements total and the repetitions no longer being allowed, one could eliminate the need for excessive feedback and consequent confusion, as the possible elements to choose for the secret key and that same secret key are both limited to four elements, it is already implied that the player is using the correct elements, reducing the feedback to only informing the player about how many elements are in the correct position. Then, the role of colour in the original game was replaced by using real physical objects - through Makey Makey [3] a circuit board that connects any conductive physical object to a computer by replacing the keyboard and mouse click signals with touch on real objects - and a distinctive sound, elicited when the player touched the object (and repeated in a sequential order at the end of each round) was associated with each one of the objects. Through this step the distinctive aspect of the elements was improved and the availability of information about the last play was reinforced by repetition and auditory memory. Finally, verbal feedback about the number of right positions in each round provided enough information for trying new combinations and derive the secret key, without reducing the challenge of the task. Still, the availability of information about previous plays needed to be further addressed. Possible trajectories were adding more features to the prototype (decreasing its simplicity) or improving the ability of the content to be remembered. Research has shown that blind people seem to be more efficient in remembering routines and patterns [4] and have more efficient auditory short-term and long-term memory [5] - although there are differences between congenital and non-congenital blindness in the accuracy and fidelity in memory tests[6]. But what kind of sounds would work better to help users recall the last sequence? In designing auditory cues in a user interface a distinction is made between auditory icons, earcons and speech [7]. An auditory icon is a brief sound that is used to represent a specific event, object, function, or action. They are essentially emulations or caricatures of naturally occurring sounds in everyday life taking advantage of the user's prior knowledge and natural auditory associations between sounds and their results [7, 8]. They can represent directly or indirectly, either by using the sound made by the target event, or by substituting a surrogate for the target - requiring additional learning to develop the relationship between the sound and a specific event [7]. Earcons are brief, nonverbal, distinctive audio sounds used to represent a specific event, usually abstract, synthetic, and mostly musical tones or sound patterns that can be used in structured combinations. Since they don't deliver any natural representational value they require more learning than direct auditory icons [7]. Since with Makey Makey the player can choose any four everyday objects of his choice (as long as they are conductive), it was not possible to refer the objects by their names (speech) or a direct auditory representation (auditory icon) of each object a player may choose. The research [9] suggests that although more realistic sounds, such as auditory icons reveal greater functional utility, there may be a preference for abstract musical sounds. Therefore we sought to find a compromise between the realism and the abstraction of the designed sounds, in order to provide further meaning to the user, exploring different levels of meaning either in the relationship between the sounds, or in the semantic and naturalistic relation that the sounds have in relation to the learning process of the users. Three alternatives for auditory feedback were designed and three different prototypes corresponding to those alternatives were used to test their efficiency. One alternative associates to each object a note of the pentatonic scale, considering the ease in creating recognizable melodies with different combinations of the notes of this scale provides additional melodic information over tonic sounds, introducing a second level of meaning that might strengthen memorization. Other alternative links voices of animals (cow, rooster, cat, sheep) reinforcing the recalling power through association with realistic sounds that are clearly identifiable to users and through conceptual immersion on the animal topic. The last one uses the sounds of vowels ("a", "e", "i", "o"), using basic speech sounds with a long history of learning and semantic and sequential value - providing an order familiar to most users -, that may benefit memorizing strategies. The main hypothesis of the present study predicts that blind users will consciously benefit from the auditory feedback provided and use it to better recall previous sequences. The second hypothesis predicts that, although users may find it more enjoyable, they will benefit less from the feedback that doesn't provide semantic or conceptual information. The prototypes were developed with the Scratch tool [10], a programming platform, developed for children, that allows simple and easy programming through direct manipulation of blocks and visual elements.

2 DATASET

2.1 SAMPLE

The study took place over a period of two months at the headquarters of Acapo Coimbra carried out by students of Master Human Computer Interaction (HCI) of IPC Coimbra. We performed a set of nine individual sessions with blind volunteers, divided between 5 males and 4 females with ages ranging from 21 to 66 years old, education levels between the 4th grade and post-graduation, and a diverse background of job occupations. Although only approximately half of the volunteers had smartphones, we found that almost all of them were already familiarized with a computer, whether it be in work related tasks or leisure. It's also noteworthy mentioning that most of them were not used to play video games, playing more palpable and physical games instead, like cards, dominoes and various board games.

2.2 METHODOLOGY

Each session took around 30 minutes and were employed different qualitative research methods:
1) a semistructured survey (Initial interview); 2) a set of three usability tests ; 3) three retrospective think aloud (one after each test) ; 4) a questionnaire which was rated through a Likert scale [11] (a tool used in which participants are asked to respond to statements on a scale ranging from "strongly agree" to "strongly disagree")

2.2.1 INITIAL INTERVIEW

We started with a semi-structured interview where we collected data on the following topics:
- Demographic data; - Education; - Occupation; - Computer usage frequency; - Smartphone usage; - Games and computer games habits.

2.2.2 USABILITY TESTS

Before starting the usability tests we introduced the game prototype to each participant so they could have a first contact with it and clearly understand the rules of the game. We tested three different versions of the game in which the order of the tests was randomized for every participant. Each version consisted in ten rounds in which the user could try to guess the correct key. The different versions differed on the feedback that was transmitted to the player about the outcome of each round of the game, one had a pentatonic scale, the other had animal sounds(a rooster, a cat, a sheep and a cow), and the last one had spoken vowels ("a", "e", "i","o").

2.2.3 RETROSPECTIVE THINK ALOUD

At the end of each test the participants were asked to explain their reasoning in the game in order to guess the correct key. Think aloud methods are often used when trying to detect usability problems. The most successful form of think aloud to use together with a system is a retrospective think aloud methodology (RTA), which means that participants verbalize their thoughts after completing a task or a set of tasks. RTA allows the participant to complete a task on their own and in silence.

2.2.4 QUESTIONNAIRE

At the end of the series of tests, participants were asked to answer a questionnaire based on a Likert scale, in order to gather feedback about the comparative efficiency of the different approaches.The scale has five-level Likert item, that means: 1) Strongly disagree; 2) Disagree; 3) Neither agree nor disagree; 4) Agree; 5) Strongly agree. In the questionnaire, 8 questions (statements) were considered for evaluation by the users:
Q1 - It was easy to remember the previous combinations when I heard the pentatonic scale.
Q2 - Listening to the spoken vowels helped me more than listening to the pentatonic scale.
Q3 - It was difficult to remember the previous combinations when I heard the animal sounds.

Q4 - It couldn't guide myself by the sounds.
Q5 - Listening to the pentatonic scale helped me more than listening to animal sounds.
Q6 - It was easier to remember the previous combinations when I heard the spoken vowels.
Q7. – Listening to the animal sounds helped me more than listening to the spoken vowels.
Q8 - The sounds only hindered me

3 RESULTS AND DISCUSSION

Results show that the users were overall more successful with the prototype using animal sounds and sounds of vowels than the prototype with pentatonic notes as feedback. The figure 1 presents the number of users that successfully identified the correct key for each version of the prototype: pentatonic scale (22%), the spoken vowels (44%) and the animal sounds (56%). Note that the spoken vowels as well as pentatonic scale versions of the prototype present a small accuracy, (less than 50%).

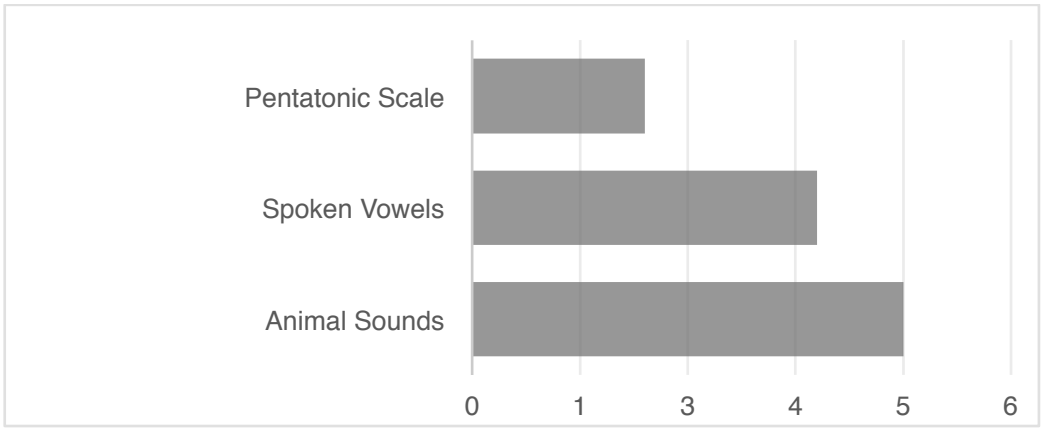

Figure 1. Number of users that successfully identified the correct key for each version of the prototype

Figure 2 refers to the number of unsuccessful tries (in 10) for each version of the prototype, by user. Results show that the spoken vowels version presents in average (5.25) less tries for the user to be successful, with the version where users were more successful – animal sounds – requiring in average a greater amount of unsuccessful tries (5.6) and the pentatonic scale version, requiring less tries (4) for the only two users that complete it successfully.

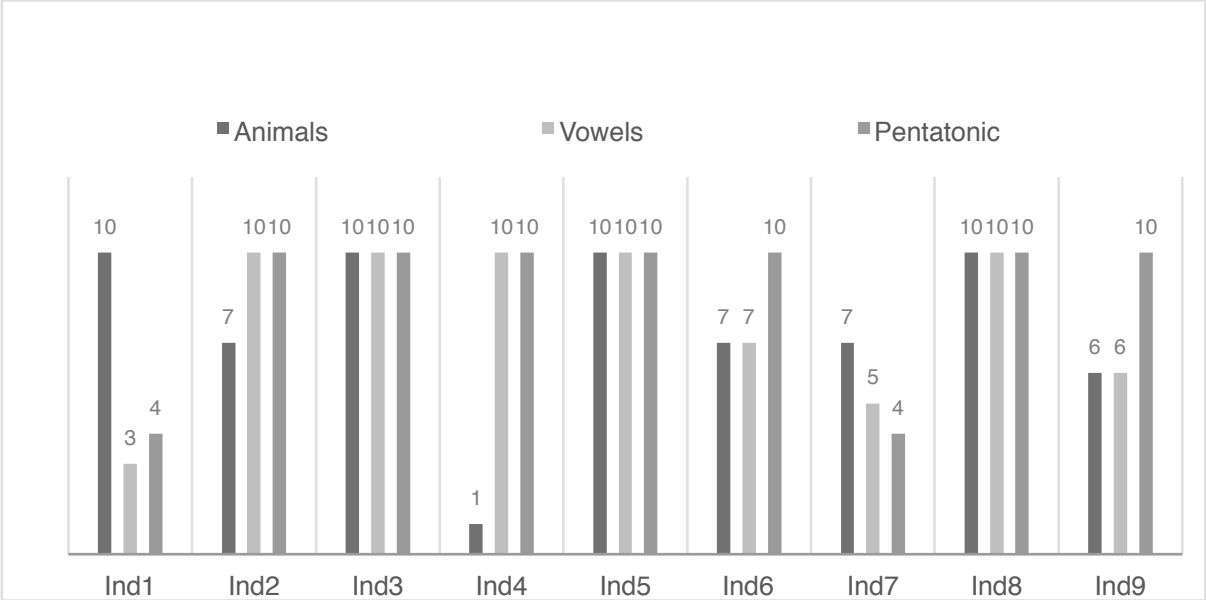

Figure 2. Number of unsuccessful tries for each version of the prototype, by user

The think-aloud was fruitful to understand the importance of auditory stimuli or other strategic references for memorizing sequences. Figure 3 shows that users describe paying attention to sounds, alone or in combination with spatial awareness, only in the versions with animal voices or with vowels; in the pentatonic notes version the users describe consciously ignoring the sounds.

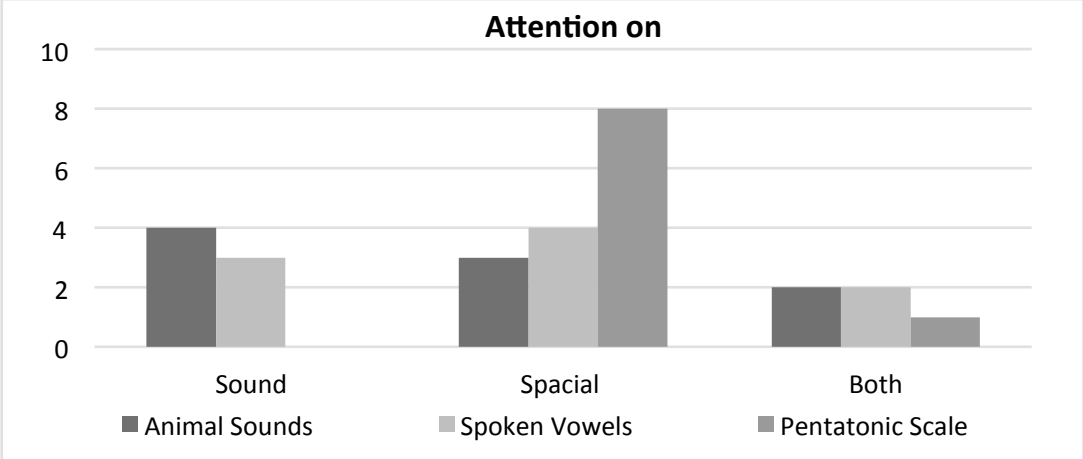

Figure 3. Version Attention

In the end of the tests, as explained in the last section, a questionnaire was done to better understand the use rand their interaction with the system. In table 1, the average of classification by all participants is presented for each question (Q1 – Q8). The results are consistent. The animal sounds are presented as the better alternative compared with both the vowels sounds version and the pentatonic notes version - which, comparatively, is the worst alternative. Both think-aloud and questionnaires results indicate that auditory feedback was not the only variable, and often not the most important, for recalling previous sequences. Spatial awareness of the objects seems to play an important role in this process.

	Classification		*Classification*
Q1	3	**Q5**	3
Q2	4	**Q6**	4
Q3	2	**Q7**	4
Q4	3	**Q8**	2

Tabela1. Classification Results – Average of Likert Scale

4 CONCLUSIONS

In order to understand what kind of sounds would work better to help users recall the last sequence, three types of auditory feedback were designed. The main hypothesis predicted that blind users would consciously benefit from the auditory feedback provided and use it to better recall previous sequences. Although users describe having used more often spatial awareness as a strategy to recall previous sequences, they were actually more successful when they paid attention to sounds, alone or in combination with spatial awareness. The less they used auditory feedback the less successful they were. The second hypothesis may provide an explanation for the differences in users behaviour regarding attention to auditory feedback. Predicting that users would benefit less from the feedback that doesn't provide semantic information, was an assumption made on familiarity with the sounds (animal sounds, vowels) and the very structure of semantic memory. A sound like pentatonic notes that are less distinct, less familiar and is semantically irrelevant to the user, provide less power to the recalling process of previous sequences. Therefore, Masterblind can be an usable experience to blind people, as long as it uses semantically significant auditory feedback. Overall, the study offers evidence that an adaptation of a board game, such as Mastermind, that relies mostly in visual information can be successfully adapted to blind users and still provide a challenging and enjoyable experience - even with users that have little to no experience in computer games.

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