An exploratory study on non-visual mobile phone interfaces for games

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ABSTRACT

Conventional games (computer, mobile, and console) rely heavily on visual information to convey the gameplay and to drive the interaction with the player. With the rapid evolution of graphics hardware and Computer Graphics, this becomes more pronounced. An undesirable consequence of this trend is that visually-impaired people get more excluded from the play. Mobile phones are pervasive nowadays, and can reach a potentially large user base, including the visually-impaired. However, in mobile gaming there seems to be only few alternatives to serve this community. This work presents an exploratory study on non-visual mobile phone interfaces for games. It is based on Semiotic Engineering principles, and emphasizes communication through aural, tactile and gestural signs. Results include a number of issues that can be incorporated to a wider research agenda about mobile gaming accessibility.

Author Keywords

Mobile games, non-visual games, accessibility, audio games, haptics and gestures, visually-impaired users, semiotic engineering

ACM Classification Keywords

H.5.2 [User Interfaces]: Interaction styles
I.2.1 [Applications and Expert Systems]: Games

INTRODUCTION

This work presents the preliminary results of exploratory research on non-visual interfaces to mobile phone games. Our main objective is to start learning about the challenges and opportunities involved with this kind of technology, and our motivation is twofold. On the one hand, we want to contribute to the design and development of accessible games for visually impaired users in this kind of environment. On the other, we want to explore new kinds of mobile gaming experiences for sighted users.

We developed a prototype mobile phone game and carried out an empirical pilot study with a small group of participants in order to see what issues emerged naturally form their experience. Three of them were sighted users familiar with traditional computer games, where visual signs are prevalent, and two were visually-impaired people that are currently unable to play mobile phone games due to a lack of accessible interfaces.

The prototype game interface was designed according to specific semiotic principles. The most salient feature of the design is the complete absence of visual signs. All game interaction is based solely on aural, gestural and tactile signs. For the empirical pilot study, we used qualitative techniques to collect and interpret data. Our preliminary results point to a number of interesting research issues that do not seem to have been addressed systematically to date.

In the next section we discuss aspects of game HCI that are important for the present work. Then we discuss related research (third section) and briefly describe our prototype game, *The Audio Flashlight* (fourth section). Next we present the semiotic engineering of the game interface (fifth section). In the last two sections we present a preliminary evaluation of the gameplay (sixth) and our conclusions (seventh).

GAME HCI

In recent years, game graphics and sound have reached an amazing level of realism and received most of the attention from the game community. However, computer game research still lacks a robust theoretical foundation, in spite of game itself being as old as human culture [15]. Modern game design fundamentals [2, 32] have greatly expanded the early theoretical concepts of Chris Crawford [8], but they are yet far from a complete conceptual framework. One of the underdeveloped areas is HCI in computer games [37] - which is a contradiction, because interaction shares

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many characteristics that prevail in games. Crawford [8] even says that "interactiveness is an index of gaminess"

The traditional focus of HCI is on usability, which underlines the productivity and facilitation in accomplishing user-defined tasks. Software interfaces should be easy to learn, use, and master, which is somehow opposite to games that are usually easy to learn, but difficult to master [21]. Barr and co-authors [3] point out that computer games are not made to support external, user-defined tasks, but instead define their own activities for players to engage in. Understanding these differences is the starting point for Game HCI.

There is a number of topics in Game HCI, but works on game semiotics [23], heuristics [9], accessibility [16], and presence [30] require immediate attention from the game research community and industry.

Semiotic analysis of computer games is proposed by several researchers. The work by Myers [23] very convincingly characterizes playing computer games as a form of semiosis. Caldwell [7] analyzes the user interface of a particular turn-based strategy game (Civilization II) using semiotics. But, as far as the authors know, the present paper is the first one to employ semiotic engineering principles specifically to mobile game design.

Regarding accessibility, according to IGDA [16], Game Accessibility can be defined as the ability to play a game even when functioning under limiting conditions, which can be functional limitations, or disabilities – such as blindness, deafness, or mobility limitations. An important source of games for users with special needs can be found in the AudioGames web site [www.audiogames.net]. In the specific case of visually-impaired users, games roughly fall into three categories [13]: games not designed to be accessible (like conventional games); games designed to be accessible (like audio games); and games adapted to be accessible.

Moreover, presence is an important factor for games. It is the perception of being in a particular space or place. Presence in virtual environments has been viewed in different perspectives [4, 20, 36], but all approaches are related to the sensorial experience of users. The literature on presence in games, however, is scarce [30].

The prevalence of visual over other senses in a game becomes more pronounced when one realizes that many games have an option to "turn off sound" completely. The game can still be played and enjoyed. Hence, sound can be regarded as a subsidiary resource. But, how many games have an option to turn off the graphics?

Haptics have also been extensively used to enhance the sensorial experience of gamers. Video game consoles have long been supporting "force feedback" joysticks and other input devices. For example, in 1997 Nintendo released the Rumble Pak [31], an accessory to connect to the Nintendo 64 [24] joystick to produce tactile feedback.

Presence can be enhanced by the expansion of the game Magic Circle that is the mental universe created when the player enters the game. This term was first introduced by Salen and Zimmermann [32], inspired by Huizinga's play-ground [15] and Roger Caillois' "second-order reality" [6]. The Magic Circle is expanded by imagination, which allows users experience real collisions as joystick vibrations or even a flight over the scene. Liljedahl and co-authors [18] explain this in terms of what they call the "scary shadow syndrome" – an event may cause greater impact imagined than seen.

Mobile Games

Mobile game design is several steps behind PC and console game design. In particular, cell phones still remains a casual gaming platform despite recent technological advancements [5]. Problems with haptics and game accessibility are especially acute.

In the mobile world, haptics has typically not been used in game interfaces, despite the built-in motors available in many phone models. Only recently has it caught the attention of the mobile game market, through such initiatives as the VibeTonz system [35]. VibeTonz provides a tool to implement applications on mobile phones that use haptics feedback.

Accessible mobile games are scarce. Although mobile devices are rapidly becoming more powerful, with more memory, more processing power, and more multimedia functionalities, such resources have not been used to promote accessible gaming interfaces yet. Additionally, as is the case with most accessible technologies [34], explorations with non-visual game interaction clearly opens up novel possibilities even for sighted users.

Another interesting peculiarity of mobile phones is that they are intrinsically connected to some network. This means that developing multi-player games for those devices is a natural move, and can be an opportunity to increase social integration among players (both sighted and visually-impaired as well).

Benefits of Non-visual Games

Research on non-visual games can generate various kinds of benefit:

- An opportunity to include a visually-impaired audience into play, by creating a game design and environment that is favorable to them;
- An opportunity for gameplay innovation in trying to represent the game environment, characters and events using audio and tactile feedback;
- An opportunity to explore and exercise other senses;

- An opportunity to create more personalized experiences, as people imagine things in different ways; and
- An opportunity to increase the immersive experience in a game.

RELATED RESEARCH

Using semiotic theories to design sonic signification systems is a strategy previously used by Pirhonen and co-authors [29]. The authors propose a design method for non-speech sound systems based on structural semiotics using syntagmatic analysis. They specifically discuss the needs of visually-impaired users, but focus on web accessibility, not games.

In another work [22], Murphy and co-authors discuss the combination of audio and haptics to convey information to visually-impaired web users. Again, as in previous work, the authors resort to structural semiotics as a theoretical basis for designing non-speech signification systems.

One attempt to explore gestural input and tactile feedback with mobile phones is that proposed by Linjama and Kaaresoja [19]. The authors describe their "bouncing ball" demo, where the user taps the device to change the ball orientation, and the demo responds with vibration when the ball hits the walls.

Ur-Rehman and co-authors [33] describe a system to represent information from a live soccer game (non-interactive, as on television) into vibration sensations on a mobile phone to convey what is going on in the game. However, as is the case with the work of Linjama and Kaaresoja, ur-Rehman and co-authors are interested in tactile feedback as *complementary* modes of communication and representation to be used with visual modes.

Friberg and Gärdenfors [12], however, explore three games (for PCs) based on audio initially targeted at visually-impaired people. They explain a model inspired on film music conventions to design the audio. They also present a semiotic analysis of the sound objects in the their games. Their work is based on that of a cartoon and comic scholar – Scott McCloud – who proposed a semiotic model of visual vocabulary based on Charles Peirce's triangular sign structures [28].

Beowulf [18] is a game for personal computers (PC) where the player wanders in a labyrinth using audio to navigate in the environment and to fight enemies. Their authors define the game as an "audio-mostly game", because the majority of gameplay is driven by audio and not by graphics. The visual information comprises a representation of the game world map with no details, displaying the areas already explored by the player.

That work presents the game sound design with a classification of the sound elements in the game. Although not designed for visually-impaired people, the authors define and explore the "scary shadow syndrome" concept. The idea is also present in *The Audio Flashlight*.

Along the same lines, the AudiOdyssey game [14] is an accessible PC game with audio and visual information. The game aims at offering a multi-player (online) environment where sighted and non-sighted players can play equally and, in the authors' words, "with the same level of challenge and sharing a common game experience".

The game is defined as a "rhythm game", where the player incorporates a DJ whose task is to keep the audience happy on the dance floor. The player generates sound in real time by responding to the music beats. The player interacts with the application with the keyboard or the Nintendo Wiimote [26]. The Wiimote is an input device for the Nintendo Wii [25], based on motion sensing capability. Using this input device makes it possible for visually-impaired (and sighted) people to play the game with a more natural and intuitive interface. When listening to the speakers, players have cues to guide themselves on how to swing the Wiimote in order to play.

In the mobile phone world, The Songs of the North [11] is a location-based game based on the Finnish mythology. In this game, player may have to interact among themselves to accomplish some tasks. This game was also not designed for visually-impaired people, but it uses audio as the primary information channel.

THE AUDIO FLASHLIGHT

The Audio Flashlight is a "treasure hunt" game we have developed for the purposes of this particular research study. The game takes place in a dark room, where the treasure is lying somewhere.

While inside the room, the player cannot see anything. All s/he can use to find the treasure is a special device called "The Audio Flashlight". This device can be regarded as a kind of radar that guides the player to the treasure through sound.

Occasionally, the player may bump into walls or other internal obstacles that lie around the room. The player should dodge these obstacles and keep walking in search of the treasure. Figure 1 illustrates a typical map for a room in this game.

The platform chosen to test the game concept is a Nokia N95 mobile phone [27].

THE SEMIOTIC ENGINEERING OF THE AUDIO FLASHLIGHT

Following the trend of some previous works, ours was also inspired by semiotics. However, unlike authors who have resorted to fundamental semiotic theories, we have used Semiotic Engineering [1], a theory of Human-Computer

Interaction with semiotic foundations stemming mainly from the work of Peirce [28] and Eco [10].

The main tenet of Semiotic Engineering is that interactive systems designers actually communicate with users (at interaction time) through computer systems interfaces. Interfaces act as the designers' proxies (the *designers' deputy*, according to the theory). Thus, when designing any system's interface, designers are actually deciding what kinds of conversations they will have with users, using which modes and media, and for what purposes.

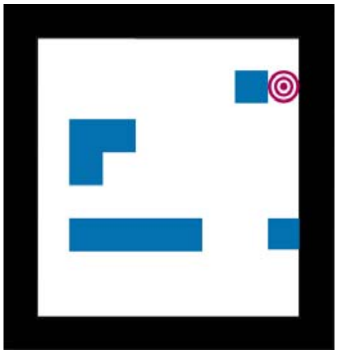

Figure 1: A typical room in the game. Blue squares are internal obstacles and the bull's eye is the treasure location

Given the exploratory goals of this project, we selected a simple "treasure hunt" game for mobile phones as the test-bed for exploration, *The Audio Flashlight*. Our design challenge was to communicate to our users the whole idea and experience the game without using a single visual sign. Instructions on how to play and game initialization procedures were provided by the game designer in person, and fall outside the scope of the current study.

Our first step was to identify the critical meanings we wanted to convey to the users. We decided we needed the following kinds of signs:

- A sign to represent that the game has begun;
- A sign to represent that the user has decided to abandon the game;
- A sign to represent that the user has accomplished the game goal (i.e. has found the treasure);
- A sign to indicate that the user is walking around the environment;
- A sign to represent that the user is doing nothing;
- A sign to represent the current state of the user relative to the game's goal;
- A sign to indicate every single action that the user can take;
- A sign to represent the obstacles that may hinder the user's walk.

Choosing the Signs

An important step in the Semiotic Engineering of the game's interface was to choose the appropriate signification system(s) that user and the designer (*i.e.* the system's interface) will use to communicate with each other, excluding systems that rely on visual representations.

Signification system choices must be based on cultural conventions usually associated to the messages that need to be communicated in the game. Otherwise, users will be required to learn an unfamiliar and arbitrary signification system to play the game, which is surely a source of usability problems. We resorted to visual games interfaces, which often apply such cultural conventions as ancillary reinforcements to communication. For example, to increase the perceived sensations and emotional setting in the game, sound and music may be used, as well as tactile signs of different sorts. The role of cognitive metaphors [17] is particularly important in this setting.

Game Events

The sign to represent that the game has begun corresponds to an "opening door" sound, relating to the metaphor of "entering an environment".

The sign to represent that the user has decided to abandon the game, before or after finding the treasure, corresponds to a "closing door" sound.

The sign to represent that the user has accomplished the game goal corresponds to sound conveying "applauses".

Note that all three meanings are conveyed in aural mode, based on signs that express primitive metaphors associated to their object.

The Radar

The sign to indicate the current progress of the user toward the game goal is represented with musical patterns, through volume and rhythm variations. The metaphor here is that of an "audio radar". Hence, the player must use his/her hearing senses for orientation within the environment.

The audio radar is designed as a set of music files with varying volume and rhythm. Figure 2 illustrates a schematic view of the audio radar.

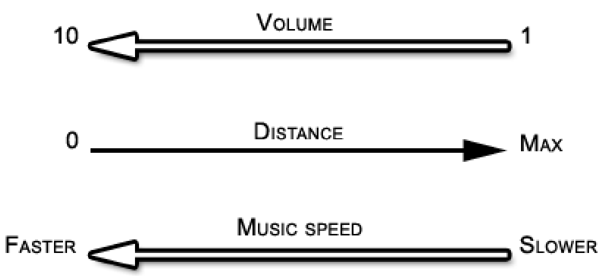

Figure 2: Schematic view of the audio radar

The music spectrum is divided into five musical patterns. All of them are very similar, but they differ in rhythm. The radar selects the pattern according to the distance between the player and the secluded treasure. The closer the player gets, the faster is the music plays. The radar also changes the music volume using this strategy. The closer the player gets to the target, the louder the music. Thus we achieve a redundancy of dimensions within the same signification system – volume and rhythm reinforce each other in conveying the user's status with respect to the ultimate goal in the game.

Player Actions

The signs to represent the user actions are represented through a gestural interface.

In the game, the user can walk around the environment in four basic directions: forward, backward, left, and right. The user communicates this command to the game by turning the mobile phone screen in the desired direction. For example, when turning the mobile phone screen to his/her chest, the player walks backward. When turning the mobile phone screen forward, as trying to point out something on the ground, the player walks forward. Figure 3 illustrates these gestures.

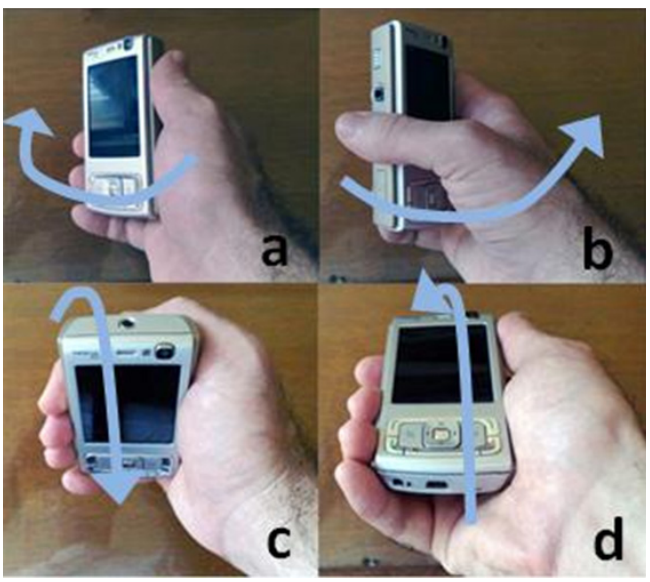

Figure 3: Gestures for walking in the environment: (a) left, (b) right, (c) backward, (d) forward

While the player is walking, s/he hears the sound footsteps in constant pace. The player remains walking while keeping the phone screen turned to the desired direction. The player stops walking by positioning the phone screen up, parallel to the ground. The sign to indicate that the user is idle (not walking) is "silence": the footstep sound is not heard.

The gestural sign to communicate that the player wants to abandon the game is to position the phone screen facing the ground.

The main motivation to adopt a gestural interface is to provide a more natural way to interact with the phone. Compared to pressing buttons to signal those commands, for instance, gestures are clearly more direct and expected to be easier to perform.

Obstacles

The sign to indicate the presence of obstacles is represented using haptics, through the vibration feature of the mobile phone.

There are two kinds of obstacles in the game: the room boundaries and internal obstacles. Room boundaries are represented with long (and stronger) vibrations, while internal obstacles are represented with short (and weaker) vibrations.

The motivation to use vibrations is to associate the idea of "physical collision" with the physical sensation provided by vibration.

In sum, we notice that the system communicates with the user through aural and tactile signs, while the user communicates with the system through gestures. The game interface designer decided on this distribution guided by a general constraint on the nature of signification systems modes, and then on the most salient metaphors available in non-visual modes of signification for mutual communication.

PRELIMINARY EVALUATION

To examine the quality of the Semiotic Engineering of *The Audio Flashlight*, we carried out an empirical pilot study with the five participants. They used our game prototype in a Nokia N95 phone provided by the researchers for the test. The goal of the evaluation was to indicate some initial directions for further research, both in terms of method and issues to explore.

Among the five people who volunteered to do the test, three of them were sighted, and two were visually-impaired. One of the visually-impaired participants was totally blind, and the other had sub-normal sight that caused severe difficulties to see the visual signs on mobile phone screens and keys, but did not prevent her from moving around by herself without special aid.

Two of the sighted participants were gamers and the other was a casual gamer. The blind participant was not an active gamer, although he reported playing simple games on a PC sometimes. The other visually-impaired participant reported that she used to play some games on a PC. None of them were active mobile phone game users, given the accessibility problems of mobile phone games.

None of the play-testers had ever played a non-visual game.

The Method

The experiment consisted of a preliminary interview with all participants. The questions asked during this interview were slightly different for sighted and visually-impaired participants. Both groups were asked about their experience with games and mobile phones. However, there were some specific questions about which tasks visually-impaired performed with their mobile phones and how. At the end of the interview, all participants were asked about what they expected from the test.

Next, participants received direct instructions from one of the researchers about how to play *The Audio Flashlight*. This researcher followed a fixed script, making sure that all participants received exactly the same set of instructions. As “a surprise” ingredient in the game, the instructor did not tell participants what sound would play when they found the treasure. He just told them “they would know” when they found it.

Then the researcher started the game and let the participant play. There was no time limit for the play, although researchers decided to gently close the experiment should the participant take too long to find the treasure and get bored or tense.

Following the test, another short interview followed. In it, participants were asked to talk about their experience during the game, and about what levels of difficulty or challenges could be added to the game, given this particular interface.

Interviews were recorded in audio, and all test sessions were videotaped. All participants were sitting in a quiet place (typically a closed room), holding the mobile phone close to their lap. The duration of test sessions was two minutes and fifty-eight seconds in average, except for one (with the blind participant), which lasted much longer.

The results of the experiment are reported below, categorized according to dimensions that are directly related to non-visual games interfaces.

Overall experience

All the play testers except the blind participant, had no difficulty in finding the treasure. Sighted *gamers* were able to find the treasure faster. The non-blind visually-impaired participant found the treasure faster than the sighted *casual gamer*. The blind participant was not able to find the treasure.

All of them reported to having enjoyed game, and found it very interesting due to its unconventional approach.

The footstep sound

One thing that stood out in the tests was how the play-testers relied on the footstep sound to know what they were doing. Listening to this sound was critical to differentiate between walking and being idle.

In traditional games, where commands are activated by pressing phone keys, the “no action” state corresponds to not pressing anything. This is a clear sign for “idle”. However, with the gestural interface, the “no action” state is much more subtle to *command* (at least in this game). Participants do not always realize that their hand position is not facing forward or backward, but is actually turned up parallel to the ground.

The footstep sound was intentionally played lower than the music when the player was very close to the treasure. The researchers wanted to check whether the excitement of the music playing faster and louder would *take over* and suggest that the participant was moving towards the target. But, all the players reported getting lost in this situation.

This suggests that the footsteps were the primary system feedback that provided the constant engagement conditions for users to keep playing. The importance of primary feedback in audio games was also stressed by Friberg and Gärdenfors [12].

One sighted player reported that indicating explicitly that he was walking in room (with the footsteps sound) was a much better alternative than using an implicit indication (like the system “doing” nothing till the player hits an obstacle or a wall, for example).

The music

The music in *The Audio Flashlight* was designed to build a tension aura to the scene.

Participants reported that the music helped to create tension in the game, and contributed to create excitement, as defined in the “scary shadow syndrome” [18].

They also found the audio radar a useful tool to guide them to the treasure.

The blind participant stayed idle for long periods of time. So, sometimes the same music ended and started over again. This operation created a gap in the sound, and he thought that this was due to some game event. The other participants did not experience this problem because they were constantly moving around (and so the music changed often).

Immersion

Participants also reported that the game was very immersive. The sighted participants said that despite the absence of graphics, they still felt immersed. One of them even got startled when he was walking in room and felt a vibration due to a wall collision. This also happened to another casual tester of the game.

A sighted participant even said that the immersion experience was similar to the one with a graphics intensive game of the same kind, despite the absence of graphics.

Vibration

One sighted participant and the non-blind visually-impaired participant did not care to differentiate between walls and internal obstacle vibrations. For them, both were the same because they felt they had to dodge them anyway.

All participants except the blind one were able to use this tactile feedback to navigate in the environment. The blind player had some difficulty in using the game due to the sound produced by the vibration motor in the phone. He thought that the sound was due to some event in the game. The other play-testers, who were more used to using mobile phones, seemed not to care about this. This issue was something that came unexpected, but can be easily explained by the pronounced auditive acuity that blind people develop in order to interpret environmental cues around them.

However, it is important to notice that vibration signs must be carefully designed (and implemented) to be meaningful and, consequently, useful for both sighted and visually impaired users. For example, sometimes the interface produced vibrations too quickly, which confused the players.

Gestural interface

The players found the gestural interface very convenient to this kind of game.

The blind user acknowledged the usefulness of this approach because he could move naturally in the environment, and also faster. He reported that he would have had much trouble with the game if he was required to play with the keypad. He said that keys in current mobile phone keypads are not very different when it comes to using touch to identify them. Then, he would have to memorize the key locations to try to play the game.

As we mentioned before, when discussing the importance of the footstep sound, it is crucial to give appropriate feedback for all the events triggered by the gestural interface, or the game may become quite confusing.

Another observation was that some of the participants seemed to have some difficulty in keeping the phone in the "straight" position and often ended up walking diagonally.

One of sighted players suddenly started manipulating the phone in ways that had nothing to do with the ones required by the game. He would turn the phone around and move it in landscape position. In the post-test interview he reported that he had lost his sense of orientation and was using the phone physically as a tool to try to recover it.

Event representation

Participants reported that the representation of the events (beginning and ending of the game, footsteps, finding the treasure) was adequate. However, some of them did not notice the signs that communicate the "beginning and ending game events". They said they "did not hear it". The footstep event was the most important one to them.

As they did not know *a priori* what was the sound for the "finding the treasure" event, some of them asked if they had found it when the music reached its peak on the first time.

The game was so designed that when a player finds the treasure, the game starts over again. The game plays the opening door sound again to communicate this event. However, participants seemed not to know what to do when this happened. They looked like they had forgotten the instructions about what that sign meant.

CONCLUSIONS

The design of non-visual games is a compelling task and still not very explored, especially in mobile phones. The research in non-visual games can help to bring visually-impaired people into play, and also benefit gaming as a whole due to the opportunity of exploring other senses beyond vision.

Current mobile phones have interesting capabilities regarding audio, vibration motors, and connectivity that may help to spark novel approaches to designing games. To explore the possibilities of non-visual mobile phone games we designed *The Audio Flashlight*, a mobile phone game whose interface relies solely on audio, vibrations, and gestural input, and carried out an empirical pilot.

Our experiment showed, as expected, that sound design in non-visual game presents very specific challenges. Although sound is commonly taken as the substitute *medium* to convey visually encoded information, this encoding should be carefully designed so as not to overload the users' senses with too much information at the expense of other sensorial experiences. This may confuse both sighted and visually-impaired players. For blind players, this issue becomes really critical, and we found that sighted designers are prone to missing certain distinctions if they are not helped by blind collaborators (possibly users) at design time. The main lesson learned was *how* and *why* certain design options were not helpful to our users.

In *The Audio Flashlight* we tried to avoid auditory overloading by representing collisions through another sensory channel, touch. However, as mentioned above, the vibration motor of the mobile phone made a sound that the blind participant thought was a meaningful element in the sound signification system.

Another issue with games highly dependent on audio is that people may not be able to play them properly in some environments like public places, due to the surrounding noise. Also, the player may not feel comfortable playing the game while other people are watching and hearing what comes out of the speakers. Social and privacy issues must clearly be addressed for appropriate playability, and we were not fully aware of those in our preliminary design.

Using vibrations in a game opens up interesting possibilities to enrich the gameplay. For example, a game could use vibrations as a way to differentiate interactions with many non-player characters. However, just as with sounds, we must be careful not to overload the users' senses with too much information encoded in tactile patterns.

A game relying on non-visual senses opens up the opportunity for the players to create personalized experiences, because they can use their imagination to build up the game scenario. This can also contribute to increase engagement with the game due to the "scary shadow syndrome" concept described in [18].

The preliminary evaluation indicated that the players enjoyed the experience as being something fun and unusual to them, compared to traditional games. However, there is room for a lot of discussions. Most of all, we should notice that the only blind participant of the group was the one who experienced most difficulties with the game. Rather than being discouraged with this result, we take it to mean that we must further investigate a number of issues, some of them related to our very method of research. For example, our interview with participants must clearly touch on certain psychological attitudes of participants regarding games, regarding the test, *and* regarding their own special needs and disabilities. These factors can have a great impact on the participant's experience and performance. However, these are obviously sensitive issues to deal with, and researchers must be well prepared to identify them, understand them and deal with them.

Some possible directions for future work that we have identified are:

- To design tests based on heuristics.
- To test the game with more visually-impaired participants, trying to include not only people with different kinds of sight problems, but also with different emotional attitudes towards games. We realize we know very little about how visually-impaired people relate to what sighted people normally refer to as *games* (*i.e.* computer based games).
- To study how visually-impaired people navigate physically in the world, focusing on how they mentally conceive space and how the physically select and perceive spatial cues that contribute to building a spatial mental model. Then we can try to support their navigational strategies in non-visual game interfaces.
- To test the game with more elaborate spatial configurations, making it harder to find the treasure.
- To add some objects that can interact with the player, and find how spatial information integrates with other sorts of information in a game situation. Designing appropriate interfaces for this kind of game is likely to be a hard challenge.
- Elaborate the gestural interface, with new significant elements. For example, would the players feel better using the phone in landscape mode, with both hands? Would this provide a better sense of orientation? It is noteworthy that one of our sighted participants, when lost in the game, tried this mode of interaction to find his way out.
- To investigate how hearing and touch jointly (or separately) affect the sense of presence and immersion.
- For sighted people, we also find it interesting to study the similarities and differences between the immersion provided by audio games and graphics intensive games. How can we increase immersion in audio games? How visual games would benefit from a elaborated sound design?

As can be seen in the list above, a research agenda in this field is rich and challenging, touching on various interdisciplinary issues. Our study is only a modest step into this territory, and it raises more questions than provides answers. However, given the relative scarcity of research with non-visual games for mobile phones, and the evidence of interest, curiosity and pleasure experienced by the participants in our study, we believe this may be a good start.

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