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Loud and Clear: The VR Game Without Visuals

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Abstract. While visual impairment is relatively common, most sighted people have no idea of what it is like to live without one of the most heavily utilised senses. We developed the game *Loud and Clear* in order to have them experience the difficulties of being visually impaired, as well as to put in evidence the abilities blind people have developed, which sighted people mostly lack. In this game without visuals, the player has to rely solely on audio to complete objectives within the game. The game consists of a number of puzzle rooms the player has to solve. These puzzles illustrate the challenges of being blind in a playful setting, and challenge the player to use different auditory skills that are key to achieving objectives without vision, such as sound localisation, sound recognition and spatial orientation. The game uses audio spatialisation techniques to give the player a realistic and immersive auditive experience. Preliminary tests of this game show that players acknowledge the initial high difficulty of 'living' as a blind person, to which eventually they were able to somehow adapt. In addition, players reported feeling both immersed and educated by the experience.

Keywords: Virtual reality · Audio game · Blindness awareness

1 Introduction

According to the World Health Organisation, in 2017 there were roughly 39 million fully blind people worldwide. Additionally, there are another 217 million people that the WHO labels as moderate to severely visually impaired [4]. However, even with this massive number of cases, many people do not understand the experience of having to live without sight. Sighted people rarely experience either the challenges of (completely) lacking sight or the abilities that blind people develop to cope with those challenges. In order to give them this opportunity, learn from it, and help raise awareness about blindness generally, the game Loud and Clear was developed. This is a Virtual Reality (VR) game without visuals in which the player has to rely on audio cues in order to navigate and recognise

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the surroundings and clear objectives in the game. Taking the form of an escape-room-like puzzle game, the player is locked in a dungeon consisting of various chambers, each containing a puzzle. The player has a certain amount of time to solve these puzzles in order to progress to the next chamber and eventually escape. The puzzles challenge the player and aim to provide experience of, and insight into, what it means to be blind. Different from real escape rooms, we do not enforce a target finishing time. The player is allowed to freely explore the scenarios, and feedback is provided to help progression as time passes. The game runs on a mobile phone attached to a head mounted device, paired with headphones and a joystick. No specialised hardware is required, making it portable and accessible to a broad audience.

2 Related Work

Creating awareness about the problems faced by visually impaired people is a first step to inclusion, and sight simulators explore that by providing experiences on partial or total sight loss. Applications attempting to provide blind people with the ability to play games are widespread, either by porting games directly targeted at visually impaired people, or by adapting existing games to be playable without a display. Many solutions rely on audio feedback. Audio is both an expressive narrative medium to convey detailed information to the player, and simple and inexpensive due to the general accessibility of audio devices.

Another source of feedback for blind people comes from haptics. While this is a promising area of research to assist the blind in navigating virtual environments [6,20], it poses various constraints (e.g. on resolution, mobility and portability), which might be considered distracting to the player. For that reason, we focus on audio games.

Sight Loss Simulators. Sight Loss Simulators are a category of applications that aim to simulate a variety of visual conditions that impair vision, usually by applying image filters to the graphics of the application that try to mimic the experience of someone with one of these conditions. The *See Now* Sight Loss Simulator simulates the experience of an impaired view to its users with the goal of improving eye care [17]. The effects of cataracts, glaucoma, and retinopathy with adjustable severity are shown to the users by applying a visual filter to a Google Street View impression of their choice. The game can be played on smartphones using any capable browser. Due to the sparse design of the simulator the experience of blindness is not as immersive or intense compared to a virtual reality solution and therefore is not illustrative of people with complete loss of vision. A similar approach was also tested using different simulation glasses [7]. Simulations to create awareness are, however, not always straightforward. Silverman [18] stated that simulating blindness by trying to achieve everyday tasks (for a limited amount of time) only serves to further distance the person trying to understand visually impaired people. All that is simulated is the moment of initial shock and confusion following the loss of vision. Playing a game meant for blind people could distract the player from the initial shock, as described by Silverman, and allow the player to experience one aspect of a visually impaired person's life through the immersion of that game. Games like *Finger Dance* [10] can achieve this goal, as it was designed to be enjoyable by both visually impaired and visually capable people alike.

Audio Games. Audio games in this context are digital games focusing on audio rather than on visual representations. These games use audio cues to make up for the lack of visuals. For example, the game *Blindfold Flappy* [14] mimics the game *Flappy Bird* [12], where the player has to steer a bird in-between gaps of varying height to avoid crashing. In *Blindfold Flappy*, the sound is adjusted so that in the left audio channel a continuous tone of varying pitches represents the vertical height of the bird while the pitch in the right channel represents the height of the gap, which should be matched in order for the player to progress. An application to indicate trajectory and movements was also evaluated as a pictionary-like game converting drawings into sound [15]. Other games are especially designed to help blind people develop new skills, such as *BraillePlay* [11] helping blind children learn braille or navigate through an environment. Echo-House [2] explores how sound waves and their echo reverberations can be used to navigate in an virtual environment. Wu et al. [21] developed a game to train people on using such audio cues to echo-locate. Similarly, *The Legend of Iris* [1] aims at training the navigation skills of blind children relying just on audio. In these games the player must navigate towards sound sources and avoid obstacles and dangerous moving objects by localising the sounds they produce. The key element of *The Legend of Iris* is the use of binaural audio in order to allow the player to localise items in 3D space.

Binaural Audio. Binaural audio is the term for audio which is received with two ears; with the perceived difference in volume and timing of the received sound for both ears, the brain is able to estimate the location of the sound's origin. To blind people this property is exceptionally useful, since they often use audio in order to get a mental model of their orientation and surroundings. The first implementations of binaural audio are from 1881, when Clément Ader displayed dual audio channel headphones that allowed people to listen to a concert over phone lines [9]. After this binaural audio has appeared in music records [13] and television shows [3]. Due to its often expensive setup, it did not gain much popularity during these time over these mediums.

Our work incorporates notions from previous work, but its original focus lies on the exposure of sighted people to a "blind-like" exclusively-auditive experience, rather than on game interaction for visually impaired. *Loud and Clear* relies on binaural audio perception to help players grasp the kind of skills that visually impaired people develop to overcome challenges in their environment. Our target group is focused on people that are of good hearing (as this is a requirement for the game to communicate to the player effectively). The controls are kept as simple as possible, but as buttons are used for moving around, some comfort with using abstract movement controls on a controller is also expected.

3 Game Design

The design of *Loud and Clear* materialises the long-established conclusions of experiential learning [8] in a VR setting. The game design is guided by two main principles, building the experience that is intended to be conveyed to the player. The first is to make the player feel challenged, yet accomplished. This is intended to convey the capabilities of blind people. The second is to not overwhelm the player, as a cognitive overload could have a negative experience, and potentially cause the player to feel inept. These principles are reflected in multiple facets of the game design discussed below. In case of conflicting principles, they were solved by carefully balancing challenge and avoiding extra cognitive load.

The game is designed to be fully wearable; it runs on an Android device mounted on a headset. The device does not render any visuals but is used for head tracking to facilitate both audio localisation and the movement direction. The player can interact with the virtual world using two one-handed controllers.

3.1 Audio Design

The game utilises audio spatialisation to virtually place objects in the room, where the audio adapts to the direction that the player is looking to. Since this is the main form of communication with the player, the selection and design of audio sources and sounds has a large impact on the experience. Therefore, we categorised sound according to characteristics and requirements as follows:

- **Static sounds** exist to illustrate the environment and are repetitive in nature. Since these sounds are a constant presence, particular care must be taken that these sounds are not too distracting or irritating for the player.
- **Dynamic sounds** signify some change in the level, whether by direct or indirect player interaction. These sounds can sometimes be unexpected, hence being able to cause surprise without startling.
- **Feedback sounds** provide direct feedback to player interaction. These are sounds that result from actions, such as footsteps from the player walking around in the level, or sounds to indicate use of an item or pressing a button.
- **Voice acting** is used to provide narrative to the player, which can help illustrate a surprising or unlikely scene. It can also be used in combination with audio spatialisation. It is important that the voice acting is not patronising to the player, as this would work against the intended goal of illustrating the capacities of blind people.

In general, sounds should be reasonably pleasant so that players do not feel uncomfortable taking any new actions and can advance without sensorial/emotional hindrance, thus feeling autonomous while unsighted. Sounds must also be balanced out in such a way that the players do not become frustrated or experience cognitive overload for extended periods of time. Since identification can be quite difficult, chosen sounds should also minimise the risk of confusing multiple objects. Furthermore, it is important that sounds do not become irritating. For example, for a repetitive sound like a static background hum, we slightly modulate it over time without affecting the perception, as to not become annoying or unrealistically monotonous.

3.2 Game Mechanics

Being deprived of vision and having to rely only on audio can be demanding for a sighted person. To avoid this, the game mechanics was designed to be simple and intuitive. Requiring only simple interactions with the environment, even people unfamiliar with interactive experiences should be able to play the game.

- Players can move forward and backward in the direction they are facing by pressing a button on the controller. While traditionally a thumb stick or d-pad is used for movement, we chose to allocate forward and backward movement to two buttons to avoid the misconception that moving to the sides is an option. The player's rotation is controlled by their head orientation.
- To interact with objects in the environment (e.g., a button or a door), the player presses a button on the controller. The interaction can either be the character taking and item to keep it in the hand or simply performing an action with an environment item.
- In order to perform certain interactions, players are able to hold items, one in each hand. If players forget what their hands are holding, they can shake the controller and the held item will make an identifying sound.
- All items in the game will make sounds in order to be easily perceptible by the player. However some of them will only do so after interacting with the environment (e.g. a bell rings after pushing a button).
- From time to time, a talking companion may guide the player toward some important items that otherwise could be missed.

3.3 Gameplay

The story in the game is purposefully kept simple: the player is a skeleton locked up in a dungeon by a necromancer. This character is a guiding presence for the player rather than an antagonist. This idea was inspired by puzzle games such as Valve's Portal series [5].

The player has to escape by solving puzzles of increasing difficulty in order to progress through the chambers. Initially, the character is awoken by a knocking sound on his coffin. The player starts by interacting with the coffin door, thus opening it. The necromancer communicates with the player, explaining that he can only escape by solving the puzzle rooms. The first puzzles are rather simple, exploring the basics of the sight-less game mechanics and the basic game concepts, such as basic movement, interaction, and sound localisation. The levels will get increasingly challenging, exposing new mechanics to the player while providing less feedback, following the *scaffolding* principle [16]. During the puzzles, the necromancer guides the player, explaining chamber settings and providing hints if the player is not able to solve the puzzle after a certain amount of time. When the player clears all the chambers, the game is over.

4 Level Design

In order to challenge the players and allow them to experience the capabilities of their auditory senses, the puzzle design is geared to utilise different auditory aspects. Additionally, the player is required to combine the skills learnt in previous puzzles with more general logical thinking elements. This provides immersion and conveys a feeling of aptitude to players when they succeed.

4.1 The Tutorial Level

The initial level presents to the player the environment, story and the game mechanics. The first steps in the environment do not require visual cues, so the level is designed to ease the player's transition out of a sighted environment and provide a gentle introduction to the controls.

At first, the player cannot move and is required to leave their coffin by interacting with it. This teaches the first game mechanic the player should learn: how to interact in a simple way with the environment. After having interacted with the coffin, the player is asked to go to a corner of the room to get his missing arm. At this moment of the game, the only sound that can be heard is the sound of the pile of bones where the player should go. Now, the player has to familiarise with the sound localisation mechanic within the game. The clear and singular sound in the room is here to show that in this new environment, the only way of getting information is to listen carefully. The player then has to reach the destination and so start to use the moving mechanic of the game. The last remaining task is to locate a button by its buzzing sound, walk to it and interact with it to open the door to the next level.

4.2 Put Out the Fire

The goal of this puzzle is to help assess the comprehension of the main game mechanics previously learnt, namely, interaction and audio localisation, while introducing the puzzle element of the game.

The room consists of 3 elements: a fire in the middle of the room, water dripping from a pipe in a corner, and a bucket in another corner. Narration informs the player that the final goal is to put out the fire. In order to do that, the player first needs to fill up the bucket and then pour the water on the fire. The player is able to hear the three sound sources at the same time, and the goal is to understand the logical connection between them: first interact with the bucket before moving towards the water source. While re-enforcing the sound-only environment, this level also conveys to the player logical challenges that require deductive reasoning.

4.3 Follow the Path

The goal of the third level is to test the ability of localising an object using the sound and traverse to it upon a specific path. The player has to follow a path through the room to be able to activate the end button in order to go to the next room. If the player goes off the path, he falls through the floor and is placed back to the last successful turn he performed.

At the beginning of the path, a mouse is waiting, and flees whenever the player approaches the next turn. At the next turn it stays there, squeaking, to indicate the next turn to be followed by the player. A second mechanic has been added to this room to facilitate the player orientation: if the player starts to go too far off the path, the sounds of his footsteps change from a safe wooden floor to a dangerous cracking floor that feels about to break at any time. By combining the sound of the mouse and the changes in the footsteps the player should be able to follow the right path and reach the final button. This aims at showing that, even without vision, it is possible to navigate in a complex environment by making use of all the available information.

5 Implementation

In order to provide an immersive experience, the game needs to provide a seamless integration between software and hardware. As we do not rely on haptic feedback, the hardware is used solely for input control.

Software. The game is implemented using the Unity game engine and Google VR Cardboard library. With the cellphone attached to the Cardboard, the head movement is tracked by merging the data from the Inertial Measurement Unit of the phone and extrapolating the actual movement from this measurement. The Unity Game Engine has built-in audio SDKs supporting audio spatialisation. Unity implements a binaural head-related transfer function (HRTF) in such a way the player can experience sound directionality through filtering the head and micro-delays between the ears. Furthermore, Unity allows to set custom roll-off curves for the volume of the audio sources, such as linear or logarithmic [19]. Audio samples and model were mostly developed in house, with addition of a few pre-recorded audio samples from standard packages.

Hardware. The hardware on which the game is played is fully wearable, using a mobile phone, stereo headphones, a virtual reality headset (e.g., Google Cardboard, solely for mounting and blocking sight), and the Nintendo Switch Joy Cons. The game is run on a mobile phone running android API Level 19 and Bluetooth 4.1 (or higher). The player has to wear a VR headset in which the mobile device is inserted; the mobile device takes care of both running the game and tracking the rotation of the head while the headset blocks all external light. The headphones can be plugged in directly into the mobile device. The Joy Cons are connected to the mobile device using a Bluetooth connection. The hardware setup is shown in Fig. 1.

Fig. 1. The setup used to play Loud and Clear

6 Evaluation

The game was evaluated using player feedback, in the form of a questionnaire. This questionnaire had a pre- and post-gameplay component, in order to estimate whether the player's perspective on the experience of the visually impaired had changed. Alongside the survey, the behaviour of players was observed during gameplay and we asked informal questions about the different sounds. These observations and feedbacks were used to improve the game development stage.

We recruited 26 participants (age range 18–25, 8 female, 18 male) randomly divided in 3 groups. We did not repeat participants in order to guarantee the absence of any previous experience with the game. The 3 testing sessions were separated by one week, with one group per session. All players played the first two levels, and when there was time left in the session they also played the third level. Prior to playing, the setup and the controls were quickly introduced. Each player filled out the pre- and post-questionnaire, asking for their views on the difficulty of having to live without sight, along with a small evaluation about the game itself and the direct effects on the player.

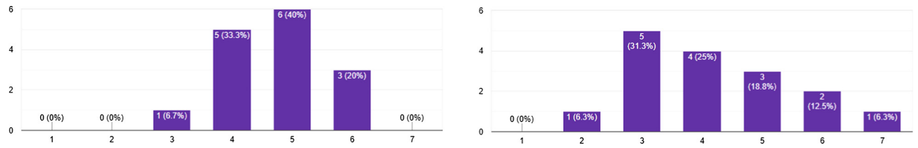
6.1 Results and Discussion

Between playtest sessions the game was improved such as to tackle the fundamental difficulties we recorded through our observations and/or feedback of the players. Elements like confusing level design, sounds that are not clearly identifiable and unhelpful or incomplete narrative are examples of points being improved between sessions. Additionally, the playtests showed that not all sounds are equally easy to identify by players. As a result, we identified and replaced problematic sounds, as well as avoided sound sources occluding each other, making it difficult for players to locate and separate audio sources.

Player skills varied greatly during the playtest sessions, with some people having a lot of initial difficulty in locating objects in the tutorial level, while other people finished the game almost as fast as the developers. In either case, everyone improved in locating a sound source during a play session, being clearly faster towards the end of the game. The identification of objects by sounds was fairly easy for the players, and definitely not a major challenge to overcome. In addition, almost every player managed to get through the end of the game.

For many players, it was rather difficult to estimate how far a sounding item was. Indeed, detecting extreme relative distances is quite easy, e.g., when an item is really far or really close to the player; but distinguishing between two intermediate distances turns out to be rather difficult. In the absence of reliable hardware to mimic haptic feedback, collision sounds provided a surprisingly effective solution. Each object has a specific sound triggered when the player collides with it. A bucket, for example, will make a metal clanking sound, indicating that you are bumping into it.

From the pre-questionnaire, our participants thought that locating objects solely by sound and doing daily tasks would be very difficult. After playing the game, they had a different view about this difficulty, finding it easier than expected (Fig. 2). The game received many positive reactions, as participants enjoyed playing the game, declaring that they had learnt from the experience of navigating in an environment based only on audio.



(a) How difficult do you think it is to locate objects only by sound?

(b) How difficult was it to locate sounds within the game?

Fig. 2. Sound localisation perception (a) before and (b) after playing the game.

On average, the playtime of one play-through varied between 10 and 25 min, revealing that getting familiar with this new environment without visuals greatly varied from player to player. According to feedback from the players, the puzzles were neither too challenging nor too hard. While some players took longer than others, they found the puzzles neither too easy nor too difficult or frustrating to solve. Solving the puzzles gave a rewarding feeling for the players. Many players stated having fun while playing the game, as well as becoming aware of what it means not being able to use your vision.

We also confirmed that reducing the available senses increases the cognitive load. Indeed, players had to focus way more than usual to do tasks that would be considered trivial with vision. Starting the game with easy challenges was, therefore, a good strategy to avoid cognitive overload in later puzzles.

7 Conclusion

The game *Loud and Clear* was developed to give sighted people a sense of the experience of being blind. By facing the difficulties of solving puzzles without using their vision, players gain a new perspective on the challenges of visually impaired people, as well as on valuing their abilities.

The playtesting process revealed hard to anticipate issues, and yielded various important improvements, including: (i) the feedback when players get close to an object, as it is often unclear when is it possible to interact with an object; and (ii) a collision sound for each object, helping players in their object interaction, to overcome the total lack of haptic feedback (on which visually impaired persons heavily rely, in their lives). As a result, players quickly became immersed in the game after getting used to the environment and game mechanics.

Our initial evaluation confirmed that *Loud and Clear* contributes towards improving awareness of the challenges of "being blind", as well as the appreciation for the unique skills developed by visually impaired people. We are currently considering how the game could be broadly disseminated, particularly through schools, which will permit a more thorough evaluation. In addition, we are also discussing deploying the game in a special museum in The Netherlands, specifically dedicated to the experience of visually impaired people.

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