An Audio Game for Training Navigation Skills of Blind Children

Kevin Allain Bas Dado Mick van Gelderen Olivier Hokke Miguel Oliveira Ben Kybartas
Rafael Bidarra* Nikolay D. Gaubitch Richard C. Hendriks

Faculty of Electrical Engineering, Mathematics and Computer Science
Delft University of Technology
The Netherlands

Abstract

Training blind children to use audio-based navigation is a demanding and risky task, as children can walk into objects and hurt themselves. Furthermore, training outdoors is dangerous due to traffic, noise and weather conditions. Having a controlled indoor environment is safer but not always available. To tackle this problem, we developed an audio-based computer game, *Legend of Iris* (LoI), specifically designed to train navigation skills.

The game is a 3D exploration game, which uses the headtracking capabilities of the Oculus Rift to create an immersive experience, and the new sound libraries AstoundSound and Phonon3D, to generate an accurate and realistic soundscape. These libraries use a head-related transfer function, allowing the player to localize the audio source in 3D space.

The design of LoI involved selecting sounds that are easily recognizable to provide cues to blind people playing the game. A subset of these cues were incorporated into the game. To verify the effectiveness of the game in developing audio orientation and navigation skills, we performed a preliminary qualitative experiment with blind children in a dedicated school. The results were rather positive, confirming that such a game is indeed a very suitable means for this purpose.

1 Introduction

Teaching blind children to be able to independently navigate helps them to develop confidence and gives them a good deal of freedom. Training navigational skills typically requires a tutor and training certain skills, such as crossing a road, can even be dangerous.

The desire to create a safe and inexpensive alternative to real-world skill training has led to the development of a number of virtual-environments and serious games, as summarized by Sanchez et al. [5] Many of the examples listed, however, concentrate narrowly on training a certain skill, often at the cost of certain game design principles, such as fun and replay-ability. Focusing on creating a fun and re-playable experience encourages a longer and more engaging play session for the child, ideally long enough that there is a significant increase in the child's skill. Several examples also make use of specialized devices, which are effective yet reduce the accessibility of the game.

In this paper we present a serious game targeted at blind children. The game, called *Legend of Iris* (LOI), is designed to train a set of skills essential to navigation. The game uses story and voice-acting to create an engaging world, lead the player in the right direction, and educate them in the basic physics of sound. The game is accessible in the sense that the only equipment required for playing is a computer, game controller and headphones. At the same time, the game has the possibility of using the *Oculus Rift* to allow head-tracking, meaning that children can orient in the game by moving their head.

*Email corresponding author: R.Bidarra@tudelft.nl

2 Game Overview

In this section, we elaborate on the main game design choices, strongly influenced by Schell's game design philosophy[6], and we justify various decisions made, taking into account this specific domain and training requirements.

2.1 Core

To motivate children to play a game meant for training, the game should be a fun and replayable experience. This will inspire children to play longer and more frequently, and thus will increase the time they spend training their navigation skills. Our game is designed as an adventure, with an absorbing, child-oriented story and engaging world, inspired by the game series *The Legend of Zelda* (TLOZ).

TLOZ consists of many different kind of puzzles. Similarly, we opted to also use puzzles as the core of our game. This resulted in the design of a number of special puzzles focused on practicing audio navigation skills. The final game is called *Legend of Iris*, and is an audio-only adventure game full of puzzles to teach navigation skills.

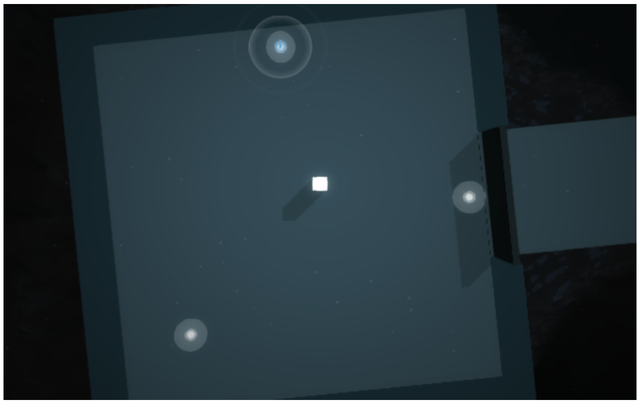
2.2 Story

If the game were to be set in the real world, and the challenges were similar to those being faced in real as well, the game would not be as fun. We decided instead to set our game in a fantasy world in which real life challenges can be disguised as story related challenges. In addition, our story continuously presents players with surprises, jokes, goals and questions in order to keep the player interested.

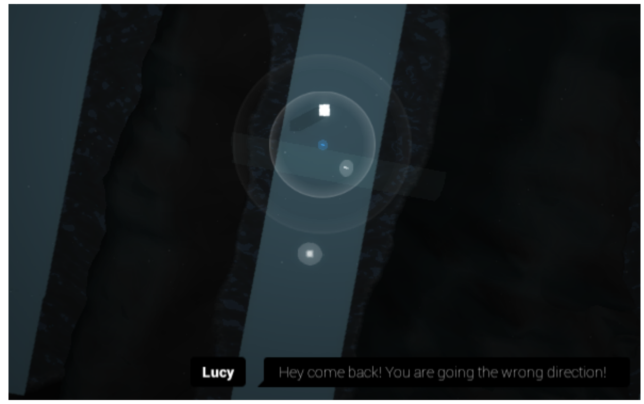
In combination with very motivating conversations, our story is designed to inspire young children to become better listeners. Once one develops better hearing skills and focus for hidden details in sound, the more one trains unconsciously for daily life as well. The earlier this is developed, the better one eventually becomes.

The story revolves around a fictional piece of software called Iris, that connects the player to a Spirit World. A fairy, named Lucy, has a big problem and asks the player for help. The player is then mentally connected to a spirit bear called Beorn. From that point on, Beorn can be remotely controlled by the player, and only what Beorn can hear is supposedly transmitted. In the first section of the game, the player is presented with several small tasks that help the player to familiarize with the controls of the game. Afterwards, the player faces progressively more difficult challenges, each of which focuses on different components of auditory navigation skills, such as:

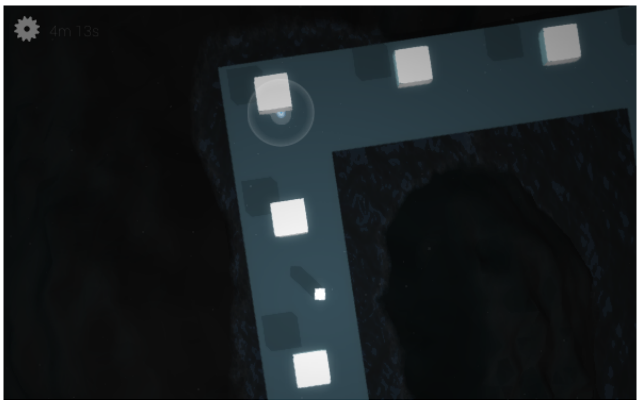
- Locating the origin of a sound
- Focusing on a specific sound in the presence of distractions
- Following moving objects by sound only
- Avoiding moving objects by sound only



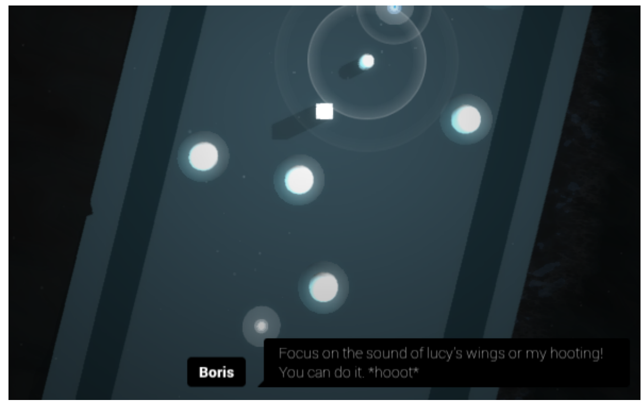
(a) The player starts in a simple room and gets introduced to the basic controls.



(b) While the player is navigating a lengthy bridge and avoiding spirits, Lucy indicates that a wrong direction is being taken.



(c) The bridge becomes harder when the player has to follow a trail of machine sounds, instead of following or avoiding a singular sound.



(d) The player has to avoid the frogs in a swamp and reach the end.

Figure 1: Some examples of the visual aids available in Legend of Iris.

- Orientation using environmental sounds
- Remember the location of a sound using spatial memory

The story additionally presents the child with education about basic sound physics, such as echo and sound propagation, providing an educational basis to the story which complements the skill training.

2.3 Controls

Feedback and controls were designed with the assistance of Rudjer Glavurtic, a blind music composer, who collaborated with us. This led to the design of several different control-schemes which can accommodate many different types of players. There is a challenge for developing controls for blind players, since controls are traditional based on players being able to see physical changes in the world to perceive movement. It is important to question every aspect, as false assumptions can often lead to undesirable results. One example found was that it was impractical to use the mouse as a means of orienting, even though this is common practice in many existing games.

A major issue with controls using only a controller, keyboard or mouse, is that it is hard for a player to know how much the character has rotated. Sound clues help, but sometimes proved to be inadequate. In real life, a person has much greater control and knowledge of their rotations, due to the balance of sensory organs and precise control of their muscles. In order to put such a precise control over the rotations of the player in the game, it was decided to allow the use of head-tracking devices. For our game, we used the head-tracking capabilities of the Oculus Rift, which proved a great improvement. The Oculus Rift helped to make the world more immersive, which complemented the entertaing story and fantasy setting.

Finally we defined our own custom control scheme using relative turns. This requires a game controller with two analog sticks, common in most modern gaming controllers. By rotating the stick in a specific direction, the character would turn its head into that direction, e.g. pressing right, would let the character look to the right. When releasing the stick, the full body is rotated into that direction, so that it becomes the new forward direction.

2.4 Visual Aids

In order to allow a teacher to guide a blind child through the game, for example if the child is stuck or if the teacher wishes to evaluate the child's performance, we have created several visual aids. When turned on, the secondary person will see a top down view of the 3D spirit world. Sound sources are indicated and for all conversations subtitles are shown. In this way, the guide can completely follow and understand what is happening in the game, without the need to actually hear the audio. An example of the visual display is shown in Figure 1.

3 Audio

One of the most important components of the game is the generation of the stimuli that form the audio cues, which the player uses to navigate through the virtual environment. Acoustic localization in its most general form considers the localization of objects in three dimensional space defined by azimuth (in the horizontal plane) and elevation (in the vertical plane). For most daily life situations, it can be argued that the acoustic objects of interest are mainly present in the azimuthal plane, which is also true for the problem at hand.

For basic localization of acoustic sound sources [1], humans use two cues which arise due to the different paths sound waves travel from the sound source to the ears: (i) interaural time differences (ITDs) due to different times of arrival of the sound at the ears, and (ii) interaural level differences (ILDs) due to different attenuation of the sound before it reaches the ears. These two cues primarily aid localization in the horizontal plane. It is the pinnae of the ears and the ears, the head and the torso that add the extra dimension of localization cues, which aid localization in three dimensions – this is known as the head related transfer function (HRTF), which provides a complete description of the effect of the body on a sound impinging the ears; the HRTF also includes the ITD and the ILD.

When sounds are produced in an enclosure such as a room, it is also reflected off the walls and objects. The resulting effect known as reverberation also affects the localization performance [1, 4]. Some reverberation may help to appreciate the geometry of the room, or even detect obstacles within it, but large amounts of reverberation will degrade the localization performance.

When creating virtual environments for audio-based games, simulation of the acoustic environment and the use of HRTFs are important. Most of the tools available today are designed to give a realistic 'feel' to the audio but there are many open questions when it comes to how this is to be done to aid the development of audio-based localization skills in blind children. At this stage, we make use of available libraries for the proof of concept of the game as discussed in Section 4, while many advanced questions will have to be addressed in future research.

4 Implementation

The game was built using the Unity game engine [9]. It has widespread use for 3D game development and is well supported and largely reliable. Unity's plugin capabilities were important for our game-specific features, such as head-tracking support and use of the head-related transfer function.

We did not implement the head-related transfer function ourselves, but rather choose to use an external library. This choice was made because such a library is sufficient for our proof of concept. Note that for future work, it would be interesting to investigate what features of sound and localization are most important for our purposes, and implement a new version of the game based on this.

The plugin we used during experiments is called AstoundSound RTI [2], a recently released Unity plugin developed by GenAudio, who allowed us to use the library for educational purposes. This library uses proprietary filters to realize, what they call, the "brain-related transfer function". GenAudio claims that it is based on years of neuro-analysis research of how the brain processes sound.

Another library we tried for applying the head-related transfer function was Phonon3D by Impulsonic, but in the version that was available during development, some artifacts are audible, in the form of clicking sounds when new audio sources are created [3]. Note that this problem is fixed in a more recent release. We have also experimented with GSound [7][8], a library for approximating reflection, refraction and occlusion effects in a 3D scene. Unfortunately it was hard to implement in our game, because GSound is not native to Unity and our scene complexity caused performance stutters in the output audio. Since the game is based on localizing audio sources, reflections and occlusion are of secondary importance, so we choose not to include GSound in our game.

To improve the immersion and realism in the game, we decided to use a head-tracking device, more specifically the Oculus Rift, a virtual reality headset. We decided to use this device because it was available to us and because it provides a Unity plugin, making implementation easier. Note that, since our game is aimed at blind users, we do not use the Oculus Rift's visual display. An added advantage of turning off the display, is that even non-blind players can experience the game as blind players would.

We made it possible to switch in real-time among the various settings of the game, such as which sound library and control scheme to use, and whether head-tracking and visual aids are available. This allows for easy comparison of alternative options, makes testing easier, and provides more flexibility for players. Logically, the options menu can also be navigated using sound exclusively.

5 Experimental setup

In order to have a first validation of the suitability of our game to develop the navigation skills of visual-impaired players, we set up some qualitative test with five participants aged 16-19. The tests, using the latest version of the game, were conducted at the Bartimeus College Zeist, a special institution for blind children.

Each test session started with a list of questions regarding the test subject's blindness, other possible disability, and his/her experience with video games if there was any. All the children that tried our game already played video games before. 3 out of 4 of the blind kids play video games on a regular basis. Some games that were mentioned are somewhat similar to our game, most notably Audiodefence and Papa Sangre, because both these games try to simulate a living world around the player using sound. Audiodefence, is a game for the iOS platform, where the user has to listen to enemies (zombies) coming his way, direct himself towards them by rotating the phone, then shoots when the enemy is in front of him. Papa Sangre is a horror-themed audio game for the iOS platform. The player controls a dead person trying to get out of a dark palace in the afterlife, and needs to save his loved one while avoiding monsters to escape Papa Sangres palace. Rotating the player is done using tactile functionality over the top of the screen, and the player should tap the lower left and right part of the screen alternatively to move forward (simulating steps when walking).

After the initial interviews, the test subjects participated in a gameplay session of around 30 minutes. Some additional guidance was provided whenever necessary, e.g. due to English instructions occasionally being unclear for Dutch test players. The testers had to progress as much as possible within the limited amount of time. During the game session, we manually kept track of some data, such as how much time the user takes from one section to another, the number of failures, or the number of requests for help. A picture of a gameplay session is shown in Figure 2.

The tests were conducted using the Oculus Rift and an Xbox 360 controller. After each gameplay session, we asked the players for their opinions and possible ideas on how to improve several aspects of the game, including fun, realism, immersion, difficulty, perceived naturalness and responsiveness of the controls and global feeling about the game world and story. We also openly asked them if they considered the game suitable for improving their navigation skills.

6 Results

Results of the questionnaire were positive and reaffirmed the potential of our game as a training tool. The blind teenagers all thought Legend Of Iris was fun, and also said that it could be used for training blind children. It is interesting to notice that most of the teenagers said they would have liked to be able to play such a game when they were younger in order to train their orientation skills.

The testers could easily use the controls, qualifying it as natural and simple. The Oculus Rifts head-tracking functions are very important to this positive point. We believe that other head-tracking devices could do the same job, although Oculus Rift was our choice because of ease of implementation and availability.

Even though we were glad about the positive feedback, we recognize that the game needs to be optimized. The game was considered as difficult by some (adult) test players, even though they were already more trained at navigation than the target audience. Additional tests aimed at the target audience are required in order to improve this steep difficulty curve.

The testers gave positive feedback on the game's realism and how the sound is being rendered. We did not execute a test with standard stereo panning on the blind test players. However, even though we ourselves are not especially trained to locate sound like blind people are, we noticed a substantial difference in gameplay performance when using head-related transfer function compared to regular stereo.

One of the important changes we made after testing our first public version was to make the story funnier and more child-friendly. Feedback from the test of the first public version told us that some elements seemed too rough for children (such as avoiding cars on a street). The first public version made us realize that several games we used as inspirations were mainly kid-friendly thanks to visually colourful characters and environments. Thus we remade the entire story. We removed every real world environment from the game and decided to directly immerse the player into a fantasy world. The feedback during the tests in the Bartimeus College Zeist was very positive regarding this change.

Even though we did not run enough tests to scientifically defend such claims, we noticed a better performance within for subjects that claimed to often play video games. The test subject that went the furthest within the limited play time was the one that claimed to play the most, while the one that went the least far was the one that only tried a video game once and barely remembered it.

Figure 2: A student from the Bartimeus College Zeist trying Legend Of Iris.

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Finally, the tests confirmed that there is a significant difference in skill between the young players. It was possible to quantify this difference by observing how far the players got within the game. While on average most people were close to the middle of the first level, some barely made a quarter of it, while a very small amount finished the complete game. Another interesting question would be to know if players would be capable of evaluating their level if we did have time to set up different levels of difficulty. We believe future tests with different levels of difficulty would be very valuable.

7 Conclusion

In this paper, we presented an audio game for training blind children in navigation skills, a task that is usually difficult, expensive and could even be dangerous. The game, called Legend of Iris, is set in a fantasy environment, making the learning experience fun, encouraging players to spend more time with it. To improve the immersion and realism of the game, we added the option of using head-tracking of the Oculus Rift virtual reality device, and a head-related transfer function for a realistic soundscape. To our knowledge, this is the first audio game specifically designed for developing navigation skills that requires no custom made hardware.

To confirm that we reached our goals, we did a qualitative experiment with a small group of blind teenagers. Their reactions were quite positive, they believed that the game can be used successfully for training navigation skills, and confirmed that the story is engaging and fun. They also confirmed that using the HRTF with head-tracking leads to an immersive experience. We therefore hope to further improve the game and incorporate it into some educative programs for blind children.

In particular, it would be interesting to do a quantitative experiment on the ability of the game to train navigation skills. This would involve a version of the game with randomized object locations. Blind children would then have to play this game repeatedly over a given period of time; and the completion times should be measured, so that we could analyze the learning curve. Such experiments could give us valuable information to confirm our choices or improve the game design. We would also like to investigate, in a similar manner, whether the HRTF is indeed better for localization of sound, and if it is necessary to implement reverberation and refraction of sound in the game.

Another interesting area for future work are the control schemes used. An Oculus Rift might not always be available, and one needs a good control scheme for such cases. In the current control schemes used in the game, it is unclear how much the character has turned. A solution worth investigating is using fixed-angle rotations on each button press.

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