ACCESSIBLE SONIFICATION DESIGN FOR YOUNG LEARNERS

Phia Damsma
Sonokids Australia,
Robina,
Queensland, Australia
phia@sonokids.com

John T. Norgaard
Sonokids Denmark,
Samsø,
Denmark
john@sonokids.com

Craig Cashmore
Peppacode,
Sydney,
Australia
craig@peppacode.com.au

ABSTRACT

Sonification is becoming more widely accepted as a valuable tool for data analysis. However, there are little to no applications developed for early introduction of students to this technology. This is particularly relevant for students who are blind or have low vision, as effective skills to use and interpret sonification can provide improved access to STEM. This paper describes considerations around the creative, accessibility and sonification design of an educational game app that introduces sonification to users who are new to this technology. In this born-accessible app, the learning process is gamified, using proven design specifications from our existing suite of educational game apps for students who are blind or have low vision. For the sonification we developed a method of mapping data to sound that could be easily understood and learnt very quickly, even by young users. This method uses only two variables: pitch, and a novel 'rhythm' of a double tone. The aim of this project was to test the power and/or limitations of pure sonification. Purposely, there is only limited visual support in the app, although the adjustable Settings allow for customization. Children can explore sonification through four different sonification game concepts and develop generic sonification skills to prepare them for future use of sonification tools for the purpose of scientific exploration and analysis.

1. INTRODUCTION

We built an accessible and inclusive-design app for mobile touch devices that offers four original educational games supporting Early Learning of sonification. 'CosmoBally on Sonoplanet' was released in March 2022 as a free app for iPad and Android tablets (current downloads 50K). The app's goals are: to build capacity in young students to use sonification, including those who are blind or have low vision; to enable them to explore and use sonification to identify shapes, trace shapes, make drawings and build spatial awareness; and, finally, to provide a proof of concept for accessible, innovative, gamified applications of sonification for young students who are blind or have low vision.
The vision is that building fundamental, generic sonification skills from a young age can help prepare students for future use of sonification tools, including for the purpose of scientific exploration and analysis [1, 2]. As students who are blind or have low vision experience barriers to access STEM education [3], early learning of skills that may remove some of these barriers has great relevance.
We consulted with students, parents, and multi-disciplinary professionals, including people who are blind or have low vision. Such as: (specialist) teachers, Assistive Technology specialists, app developers, scientists working with sonification, and alternate format production specialists.

2. SONIFICATION

The principal requirement for the sonification in the app was that young users with no previous sonification experience need to be able to easily and quickly understand how information is mapped to sound and how to extract the essential information from the non-speech sound. To confirm the best sonification design for our purpose, we tested our proposed sonification algorithm at two conferences throughout 2021 by way of a quiz ('Spaceflight to Sonoplanet'). A total of 29 adults, including 7 people who are blind or have low vision, participated. The wide majority (96%) of them proved to be able to comprehend and correctly identify the sonification of shapes after only a very short introduction (2:30 min.). This confirmed the effectiveness of the algorithm.

Prototype games were then developed for the purpose of gathering further feedback from testers around gameplay and use of sounds: a web-based prototype game and a number of TestFlight sessions on iPad.

Particular valuable feedback was received from two dedicated and enthusiastic 9- and 15-year-old students who are blind. Their findings and ongoing involvement directly impacted on the development of the app.
This underpins the importance of ensuring a basic level of accessibility in any prototype to enable serious involvement of testers who are blind or have low vision from the initial stage of the project.

2.1. Sonokids sonification design

The Sonokids Sonification Design maps a computer, tablet or mobile display as a coordinate system with X=0 and Y=0 at the bottom left corner. When you move your finger towards the top, the Y point increases and decreases when moving towards the bottom. When you move your finger towards the right, the X point increases and decreases when moving towards the left. Each X, Y point has a unique sonification identifier. If the sonification of a shape is played automatically, it starts in the top left corner, moving to the right.

2.2. Vertical sound pattern

At the bottom of the display a low sound is played twice (see "Horizontal sound pattern"). As you move towards the top the frequency, or pitch, of the sound is increasing. The higher

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a point, the higher the pitch. The higher a data point is located, the higher the pitch of the tone.

In music the terms "low" and "high" notes are used. We therefore decided to place the low sounds at the bottom of the display. For the piano "up" is used for higher notes and "down" for lower notes. Researchers confirm that pitch is the most commonly used auditory dimension [1, 4], as it uses the adjectives "high" and "low" and this is done in the same way in several music cultures [5]. Some sonification experts claim that high pitch for high value and low pitch for low value may be the most natural convention, and closest to a standard we can get [6].

2.3. Horizontal sound pattern

For movement in the horizontal plane, we took a novel approach. At the left of the display a sound (the same sound) is played twice. As you move towards the right the gap between the two sounds is decreasing. The "rhythm" is getting faster and faster as you move to the right – the tempo goes up.

"Rhythm" and "tempo" are easily perceived and intuitive to people. People used rhythm before music was invented. On a piano the frequency wave of the notes is getting shorter and shorter when you play from the left to the right of the keyboard. The double tone clearly conveys changes even in small increments, as opposed to volume as a variable, from which it is harder to pick up nuances. No stereo panning, as that requires a headset.

Tracing by dragging a finger on the touch screen over a sonified shape in the app horizontally is rhythmical - dragging vertically is both rhythmical and musical. Thinking in musical terms, each shape has its own 'melody' which may make it easier to recognize and remember. For instance, a square will always have the same melody no matter the size of it - only the key will change according to where it is placed on the screen - and smaller squares will have shorter 'melodies".

2.4. Empty space sound pattern

An "empty sound" will play and loop if you drag your finger on the screen where there is no shape. We first considered and tested the option to let empty space simply be silent. But we decided on a continuous deep ambience sound (impersonation Space) after we found that this helped testers locate the sonified shape quicker. By default, the Surround sound outside the shape is on, but you can turn it off in the Settings menu in the app.

2.5. Overtones

An 'overtone' gives extra meaning, additional information, to a data point. In advanced astronomical sonification tools, up to 20 overtones per data point may be used to enable multi-parameter analysis [7]. An example of an overtone in our app is a 'ding' sound in a shape such as a rectangle, indicating that a 'turn' is imminent. We derived the term 'turn' from how a young girl who is blind describes her experience with exploring the four sides of a rope presented in a square shape [8]. For a sonified circle we added a 'round' effect at 3, 6, 9 and 12 o'clock.

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2.6. Sound indicator pattern

Game 4 uses "sound indicators" that play automatically without the user touching the screen and allow for orientation in a grid. They use the same sonification algorithm, but additionally each "sound indicator" is a collection of sounds. It begins with a whistle sound that goes up in pitch ("take off") and ends with a whistle sound that goes down in pitch ("landing").

3. OTHER SOUNDS

Apart from the non-speech sonification, speech, or spoken feedback, is used to provide users with instructions, navigation support, encouragement, storytelling, and guidance (including from astronaut CosmoBally, with her signature sound 'C-B' in morse).

The 'Launch' at the start of the app takes the student to the alien environment of Sonoplanet (skip with 'flick right').

Soundscapes, and Earcons provide notification, create expectation and anticipation. 'Game-sounds' include the scream of resident 'Saliens', and short, fun audio plays.

People who are blind generally use an in-built screen reader on their mobile touch screen device. On iOS the built-in screen reader is called VoiceOver, and on Android tablets it is TalkBack. When turned on, the speech of these screen readers, which supports navigation via finger gestures, will interfere with the sonification and other sounds in the app. Like in all Ballyland apps, the app instructs users to turn off screen readers and switch on self-voicing menus. To navigate through the app menus with self-voicing turned on, finger gestures are needed that are familiar to a screen reader user: a quick, small, 'flick' type swiping movement with one finger from left to right to go to the next menu item (this is called a flick right), and a similar 'flick' from right to left to go back to the previous item in the menu (flick left).

4. OTHER DESIGN CONSIDERATIONS

Although the power of sonification for accessibility has shown to be enhanced when supported through multi-sensory modalities such as touch [9] and visualization, we wanted to test children's abilities using purely sonification. The app design needed to cater for children who are fully sighted, blind, or have low vision. Four games, with different sonification and game concepts enable young students to: (1) use sonification to compare and identify shapes; (2) use sonification to trace shapes; (3) explore sonification for creative purposes (drawing in sound), and (4) build spatial awareness in a digital grid (finding hiding 'Saliens'). All games are set against the backdrop of the strange environment on Sonoplanet, a planet discovered not too long ago by Ballyland astronaut CosmoBally, and where everything and everybody is sonified.

Sonokids 'Ballyland' is a suite of 12 educational game apps and software that support students who are blind or have low vision in developing technology skills. Young users of these apps know what happens primarily through sounds (What You Hear is What You See - WYHIWYS). Images and animations are used to engage sighted siblings and friends but are always kept simple and uncluttered to support those with low vision. However, for this sonification app we decided to use as few images as possible. After all, if one wants to train all users to rely on their ears to derive essential information from non-speech audio, then visuals may get in the way for those with (low) vision, because it will distract them. Instead of focusing on listening, testing demonstrated that they will try and rely on the visual input to identify a shape. By default, shapes are therefore only represented through sonification, and not with images. Still, adjustable Settings allow for customization for students with low vision or sighted teachers working with students who are blind.

We note in this context that after first submitting the app for review to the AppStore, it was not approved and deemed not functional. When we added some basic images and a text on the Homepage that highlighted that it was an audio game and users should turn on the volume on their device when using the app, it was instantly approved.

Instructions are gamified as 'Mission Briefings', and users are pre-warned to use attentive listening to derive information from the sonification (the 'Semantic Listening Experience' from the Sonification Canvas [10]). It is important to make your audience aware of the intentions of your audio [11]. CosmoBally's message in the app is clear: "Open your ears!"

We later designed a 3D printed tactile learning tool of CosmoBally with the app, to enable students who are blind or have low vision to perceive what she looks like through tactile exploration. Free copies were offered to teachers for their students to use with the app.

Finally, the app is supported by a dedicated 'Sonoplanet' website [12] with background information, lesson suggestions, and links to other educational multi-sensory sonification projects.

5. EVALUATION

As the app is meant to be used at home as well as at school, tracking user data with Google analytics was not an option. We followed the example of another educational sonification project [11] and promoted an anonymous online survey to users of the app. Through the survey and in-person workshops we collected feedback about the use of the app, students' ability to analyze the sonification and other learning outcomes from teachers and parents. We hope to present the results in a future publication.
Preliminary survey results suggest educators recommend the app for students from as young as 2, varying to students from 8 years of age, depending on the developmental level of the student.

6. FUTURE WORK

We intend to develop video tutorials for teachers and to collaborate with colleagues of the Audible Universe [13] to try and apply the same sonification mapping to another type of game interaction.

7. CONCLUSIONS

The novel Sonokids mapping algorithm for data sonification provides an intuitive and engaging way to extract shape and positional information by young users who are fully sighted, blind or have low vision. This sonification method, embedded in an accessible, gamified, interactive environment, has the potential to support educational and community outreach.

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