Enhancing Usability of OAE Hearing Screening Devices Through Visual Progress Indicators

Jiayuan Liu
Olin College of Engineering
jliu2@olin.edu

Abstract

Otoacoustic emission (OAE) devices are essential for detecting hearing impairments but are often inaccessible in low-resource settings due to high costs. To address this, we developed a cost-effective alternative designed to enhance usability through visual test progression indicators. To ensure simplicity and intuitiveness in the user interface, LED indicators were incorporated to guide users through the testing process. This report focuses on testing the assumption that an LED-based circular progress bar is an effective UI feature for this purpose.

Our user testing demonstrated that the progress circle was intuitive and preferred for visualizing test status. However, it did not significantly enhance testing efficiency or accuracy and lacked the detail required by some users. These findings underscore the need for alternative visualization methods and inform future refinements to improve our hearing screening devices UI design.

1 Introduction

Otoacoustic emission (OAE) hearing screening devices are widely utilized for non-invasive hearing assessments due to their ability to detect hearing impairments effectively. However, these devices remain largely inaccessible in less developed regions because of their high cost. This limited availability often leads to undiagnosed hearing loss, which can contribute to delays in language development and other critical milestones in children (Rai and Yashveer, 2022). To address this issue, innovative approaches have been developed, including smartphone-based screening tests (Chan et al., 2024).

In this work, we aim to tackle the challenge of affordability and accessibility by leveraging expired intellectual property to create a cost-effective and user-friendly alternative (IEEE, 2024). While the primary objective is to lower the cost barrier, it is equally important to ensure that the device features a simple and intuitive user interface that conveys sufficient information for accurate results, fostering user confidence in the device's reliability.

Previous development efforts have focused on iterative user testing of the device's interface with audiologists and professionals of varying experience levels. Feedback centered on static interface elements, such as icon clarity, light indicator colors, and the overall layout of device components. These insights informed further design improvements, leading to an optimized interface. However, limitations in design tools like Figma have restricted testing of dynamic elements, such as the behavior of light indicators and the placement of the power switch. This highlights an opportunity to enhance the design by incorporating interactive and dynamic elements, ensuring a more guided and user-friendly experience during the hearing screening process.

To explore this potential, we proposed the integration of an LED-based progress circle on the handheld device. This feature was designed to provide users with a visual representation of the test's progression and an estimate of the wait time as the ear probe plays and receives frequencies. Our working hypothesis was that the addition of this feature would facilitate more effective testing for audiologists and other potential users.

To validate this hypothesis, we developed four specific statements to be tested through user observations, preferences, and data analysis:

1. Users prefer having the testing progress visualized.

2. Visualization aids in faster learning of the device's operation.

3. Visualization improves testing efficiency and accuracy.

4. The progress circle is the most effective method for visualizing progress.

The findings revealed that users appreciated having a visual indicator of test progress, describing it as intuitive and user-friendly. While the progress circle enhanced user understanding of the test status, it did not significantly impact testing efficiency or accuracy. Furthermore, the progress circle was not identified as the optimal method for visualizing progress due to its limitations in conveying detailed information, which some audiologists and parents found essential. These results suggest that while the progress circle adds value to the device's usability, further refinements or alternative visualization methods may be required to meet the diverse needs of users.

Method

To test the assumption, an Arduino-based prototype is built and tested in co-design interviews with two professional midwives in Massachusetts and an audiologist and her assistant in Guatemala.

Section 1: Prototype Development

This prototype is a low-fidelity physical UI testing tool that cannot perform an actual hearing loss detection test. It only simulates the different testing stages and the possible scenarios that can cause the process to halt.The layout of the LEDs and buttons going from the top to the bottom correspond to a typical testing sequence. It has three phases: Debugging, Testing, Result Showing.

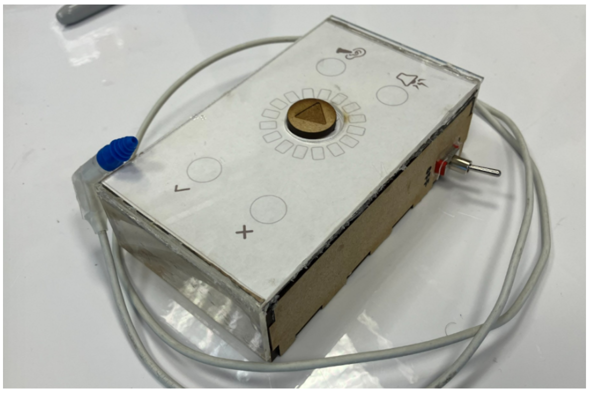

Figure 1: Arduino-based prototype that simulates a complete test run with buttons and light indicators improved based on previous design. The circular visualization of test progress is shown around the play button in the center.

In the first phase, the left light under the ear probe icon indicates how well the probe fits inside

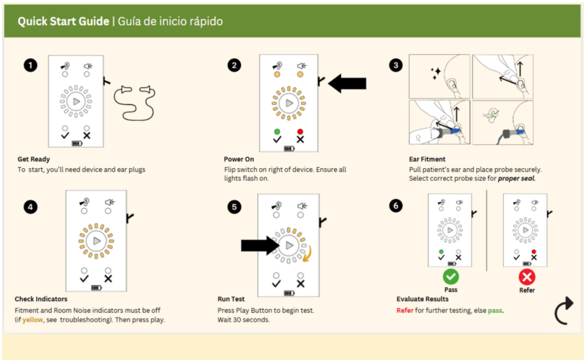

Figure 2: Prototype manual that displays the features and step-by-step instruction for using the prototyped device.

the ear canal. After the device is switched on with the power switch on the right side, all lights, including the debugging lights, progress circle lights, and result lights, are briefly turned on for 2 seconds. Then it automatically goes into the debugging phase, where probe fitting and noise level are checked respectively. If the probe is detected to be not fitting well, or if the noise level is too high for the test to be effectively taken, the corresponding light flashes until the problem is addressed. The checking for probe and noise happens in this order instead of simultaneously, because of two reasons: firstly, it only makes sense to start checking noise level when the probe is in the right position; and secondly, this helps the user to focus on one task at a time.

After the probe is well-fitted into the ear and the noise level is below the threshold, the test will automatically proceed onto the testing phase. Five yellow LED lights that form the circle around the play button will all light up to prompt the user to push the button in order to start testing.

Shortly after the toggle is set on, all LEDs turn off except for the one in the upper right direction (one o'clock direction), lighting up the first one-fifth of the circle, indicating the progress of the test is one-fifth completed timewise. After the first light is on for 6 seconds, the second light will fill up the second one-fifth of the circle. Similarly, the rest of the lights turn on one by one, with a time interval of 6 seconds, progressing clockwise and eventually closing the circle, indicating the complication of the test. Given that a typical OAE test is around 30 seconds, the completion of the progress circle will bring the user to the next phase of the test, which is the result showing.

One of the two LEDs on the bottom of the device will light up. The red light with the icon of a check mark indicates a “pass” and the green light with the icon of a cross indicates “refer”. The light will remain on until the user turns off the device.

It is worth noting that, since the purpose of this device is to understand the user’s interaction and interpretation of the UI design, the progress from the debugging stage to the testing phase is controlled on the backend by the interviewer. In other words, the user adjusting the probe and keeping the noise level low will not actually stop the indicated light from blinking; it is by keyboard interruption on the interviewer’s computer–where the Arduino is connected to–that controls the change from debugging phase to the testing phase.

Figure 3: Concept image of the MAICO OAE device used by the midwives, presented during the co-design interview. The screen displays two bars representing the frequencies that have been passed during the test.

Figure 4: In-person co-design session with the Massachusetts midwives.

Section 2: Co-design Interview

To better understand the first-time user perception of our prototype, three separate interviews were conducted. The first interview took place in person with two midwives from Birth Matters Midwifery

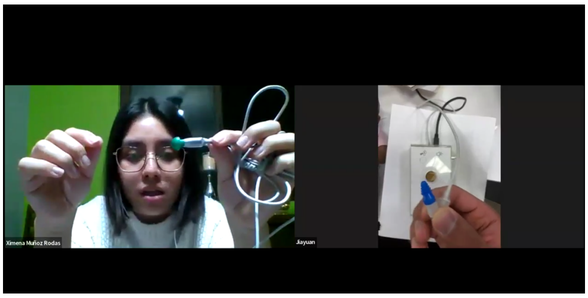

Figure 5: Virtual co-design session with Ximena, the assistant of an audiologist in Guatemala.

Care in Massachusetts, USA. Their backgrounds are summarized in the table 1.

Interviewee	Work Experience	Training Others
Midwife 1: Jessica	Worked as a midwife for 17 years	Has trained other midwives in using the OAE device
Midwife 2: Olivia	Worked as a midwife for 3 years	Has not trained others

Table 1: Background of midwives interviewed in Massachusetts.

During this session, the participants were provided with the prototype and a double-sided printed manual. They were tasked with performing a complete test using the device without receiving any verbal instructions. Encouraged to “think out loud” while interacting with the device and exploring its features, their observations and interpretations were recorded to gain insights into the intuitive aspects of the device’s user interface. Particular attention was paid to their feedback on the progress circle. Participants were asked about their understanding of the circle of lights during the test, whether its meaning was immediately clear, if they had alternative interpretations, and how they felt about this type of visualization. Following this, participants demonstrated the devices they currently use, explaining the information displayed during testing, and shared whether they preferred the prototype’s visualization over their current systems.

A similar co-design process was carried out with two additional users in Guatemala: Dr. Paty Castellano, an audiologist, and her assistant, Ximena Munoz, both of whom perform newborn hearing screenings as part of their daily tasks. Due to geographical constraints, these interviews were conducted virtually. Their information is presented table 2.

Interviewee	Work Experience	Training Others
Audiologist assistant: Ximena	Used to work as a PT, started working with Dra. Castellanos as "Tecnico Tamizaje de Neonatal"	NA
Audiologist: Dr. Castellanos	20 years as an Audiologist, 9 years in Tamizaje de Nacimientos program	Trains other audiologists

Table 2: Background of interviewees from Guatemala.

The virtual interviews were adapted to the online environment. The prototype was displayed on camera, with the interviewers ensuring that all icons and buttons remained clearly visible. Manuals were shared via Zoom's screen-sharing feature, and participants provided verbal commands while the interviewers operated the device to minimize bias. Observations of participants' verbalized thoughts, operational commands, and comments about their experiences with existing devices were carefully recorded. These sessions also focused on the information currently provided by their devices during tests and their preferences for the prototype's visualization. The Massachusetts midwives also shared their current device, the MAICO OAE (Figure 3), which features two progress bars on its screen representing frequencies that have passed during testing.

Results

After conducting three interviews with four members of our user groups, we gathered valuable insights into the pros and cons of adding a progress circle feature to our device. These insights are summarized into four main points:

1. Universal Understanding of Frequency Breakdown

During the co-design interviews, all four participants—two midwives from Massachusetts and an audiologist and her assistant from Guatemala—commented on the progress circles as "checking at each frequency." This shared interpretation indicates that breaking down frequencies and showing which ones pass or fail during testing is a common practice and easily understood by users. The feedback suggests that the progress circle helps users recognize that the test is ongoing. For those with prior experience using other OAE devices, the lighting up of sections in the circle is reminiscent of existing frequency display methods, making the feature intuitive and user-friendly.

2. Simplicity vs. Perceived Competence

Both midwives expressed a preference for devices that show minimal information during the test. They noted that devices displaying excessive data, such as continuously flashing numbers and plots, can be overwhelming and unnecessary, potentially causing distress before results are revealed. This highlights the importance of keeping the progress indicator simple and focused. However, one midwife emphasized that in scenarios where parents are present during the test, the device must also convey competence to build trust. Parents skeptical of a "refer" result may question the device's accuracy if it appears too simplistic. In contrast, the audiologist in Guatemala noted that tests in her setting are typically conducted without parents present. For follow-up diagnostics, the specific frequency results displayed on existing devices can provide valuable information for detailed evaluations. This raises a potential limitation of the progress circle: while it is simple and intuitive, it may not provide enough detail to satisfy audiologists or to reassure parents of the test's legitimacy.

3. Debugging Challenges

One midwife described using frequency breakdown profiles to "debug" results. For example, if one test passes frequencies A and C while another passes B and D, she might infer that ambient noise or a device issue caused the failure, and since all frequencies A, B, C, and D passed in one test or another, she would say the child passed the test. This practice, however, was strongly disapproved of by the audiologist, who emphasized that combining incomplete frequency profiles to generate a "pass" result is unacceptable, as newborn screening personnel should only have the person pass the test if the device has said that they pass. Nonetheless, the interviews revealed that noisy environments often affect test outcomes. The audiologist suggested that instead of showing frequency pass/fail information in real-time, the device could include a noise indicator to help test-takers identify when ambient noise is interfering with results. This would allow for unbiased retesting without misinterpreting frequency profiles.

4. Prompting and Color Feedback

The progress circle was effective in helping participants understand when to press the button and start the test, even in the presence of challenges such as blinking noise lights. Regarding color, the audiologist suggested using green lights instead of yellow to signify successful frequency passes, aligning with common color-coding conventions for positive outcomes.

In summary, these observations led us to re-examine the following assumptions:

1. Users prefer having the testing progress visualized.
2. Visualization helps users learn to use the device more quickly.
3. Visualization improves testing efficiency and accuracy.
4. The progress circle is the most optimal way to visualize progress.

While assumptions 1 and 2 were validated—users appreciated the visualization, and it made the device intuitive—assumptions 3 and 4 were found to be problematic. Visualization does not necessarily improve testing efficiency and accuracy, as the frequency breakdown profile could be misused for debugging (3 is false). Moreover, the progress circle may not be the optimal visualization method because it lacks the detailed information needed by audiologists or parents (4 is false).

Discussion and Future Work

The assumption statement and its sub-statements were crafted based on the stakeholder needs for a device that is both cost-effective and simple to learn. The decision to implement a circular progress visualization was driven by several key considerations:

1. A visual representation was chosen over text-based information to overcome potential language barriers, enhancing the device's accessibility for users worldwide.
2. The circular design was integrated into the existing device layout, encircling the central test button to minimize space usage and maintain a compact form factor.
3. The placement of the progress circle in close proximity to the play button facilitates users' understanding of how the visualization corresponds to the test's progression.
4. The use of a simple and familiar design element—similar to loading indicators found in mobile phones and digital timers—supports intuitive understanding across different user groups.

Despite these strengths, a primary limitation of this study is the small sample size and potential misalignment between the testing group and the broader target audience. While audiologists and midwives with experience using OAE devices provided valuable feedback, this group may not represent the experience of community members with little or no training. Future research should include co-design sessions involving a larger, more diverse group of participants, such as teachers, parents, and community leaders in Guatemala. These sessions, conducted under the guidance of local audiologists, could provide more comprehensive insights into how untrained users interact with the device and help refine the design to meet their needs.

Additionally, the current low-fidelity prototype did not fully demonstrate the potential benefits of the progress circle feature. Feedback from both a midwife and an audiologist highlighted that the uneven distribution of lights around the button made it unclear if dim sections represented failed frequencies. To address this, future iterations should consider incorporating additional LED lights or replacing individual LEDs with a continuous LED ring. This change would improve clarity, making it easier for users to interpret the progress information and use the device effectively in real-world settings. These improvements, combined with testing involving a broader user base, could optimize the design for greater usability and accuracy in clinical and community-based hearing assessments.

Appendix A: Prototype

The detailed Arduino code for the test simulation can be accessed at the following GitHub repository: GitHub Repository.
Petrone, J. (2024). Co-design session notes.
Erickson, O. (2024). Co-desing session notes
ADE Global Health. (2024). Final Co-design Script
ADE Global Health. (2024). Prototype Model

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