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AvatarAudiometer: an online simulation platform for pure-tone audiometry

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Live Demo: AvatarAudiometer.com

INTRODUCTION

Pure-tone audiometry (PTA) is part of an audiometric test battery that is used to evaluate the auditory system. Knowledge of and experience with performing PTA hearing exams is an essential skill in clinical audiology as well as in hearing-related research.

Students typically learn how to perform these hearing exams in-person using expensive equipment and live participants, but that is infeasible under pandemic circumstances. AvatarAudiometer aims to deliver a similarly-helpful training exercise remotely by simulating a real audiometer, the responses that real humans give during a hearing exam, and the experience of plotting audiometric data on audiograms (graphs used to illustrate hearing thresholds).

INTERFACE AND DESIGN

The main simulated audiometer component adopts a design with a layout reminiscent of a real audiometer. It contains all of the essential features of a real audiometer—controls for audio channel (left/right), transducer, volume, and frequency, plus a response indicator.

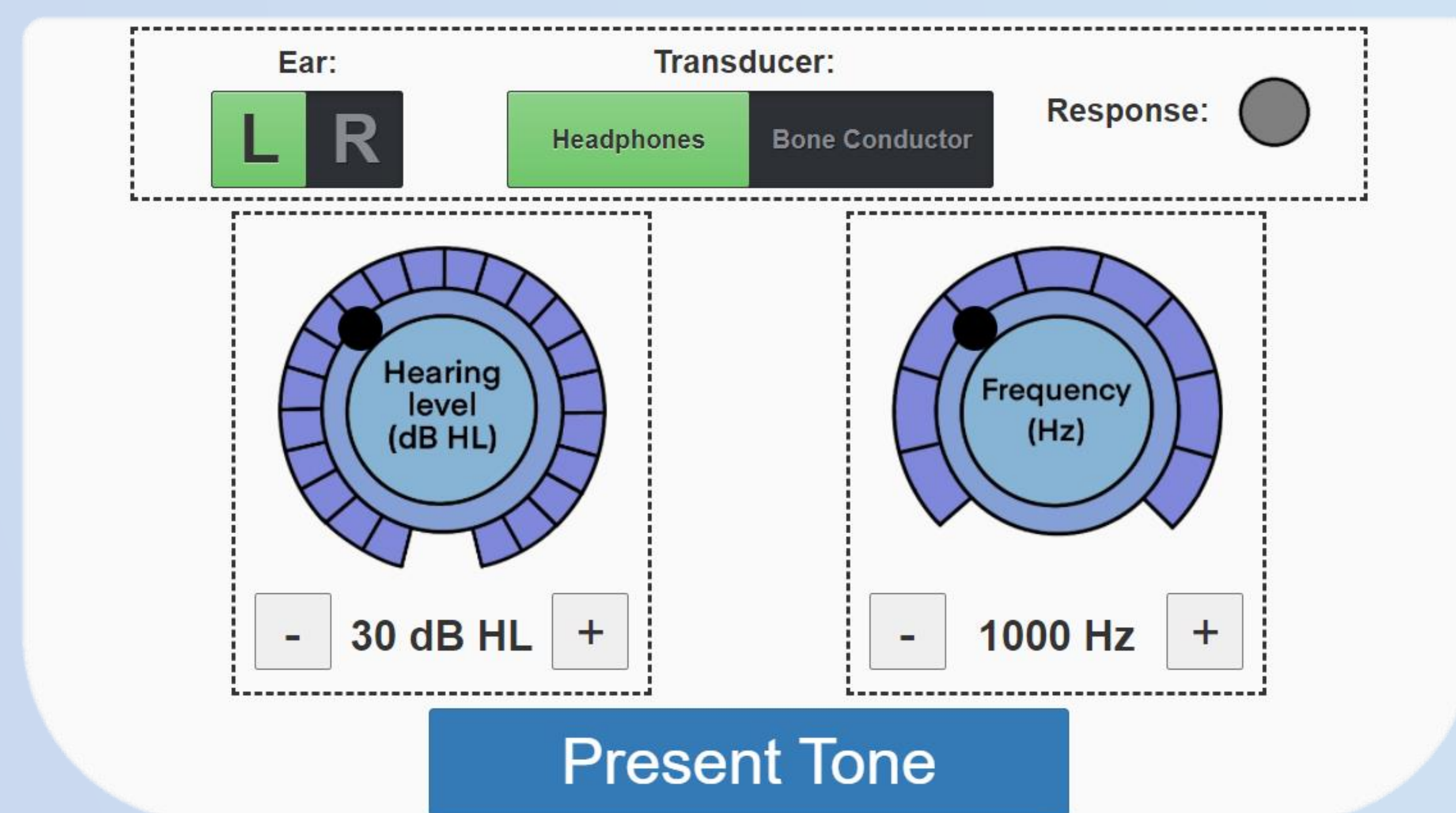


Figure 1: Schematic of Audiometer interface. Audiometer components are shown on the main interface. R = right, L = left.

In addition to simulation, a key feature of the AvatarAudiometer is the tutorial it provides to students. It walks users through each feature of the audiometer and audiogram plotting tool and describes how it can be used with text and animated visualizations.

TECH

AvatarAudiometer is built as a web app with a Python Flask server backend and a frontend built with HTML/CSS/JavaScript. Pages are generated using Jinja2 HTML templating. JQuery and Bootstrap are used for some parts of the UI. Google Analytics is used for metrics and event tracking.

PATIENT PROFILES

The simulated patients in AvatarAudiometer each have a different auditory situation and profile. They vary from one another in terms of hearing thresholds, chances of giving false positive/negative responses to tones, reaction time, and how long they hold the response for. The curated patients also have a text description of their situation—containing the kind of information they might volunteer to staff at an audiology clinic. These patients have been chosen to represent specific types, configurations, and severities of hearing loss.

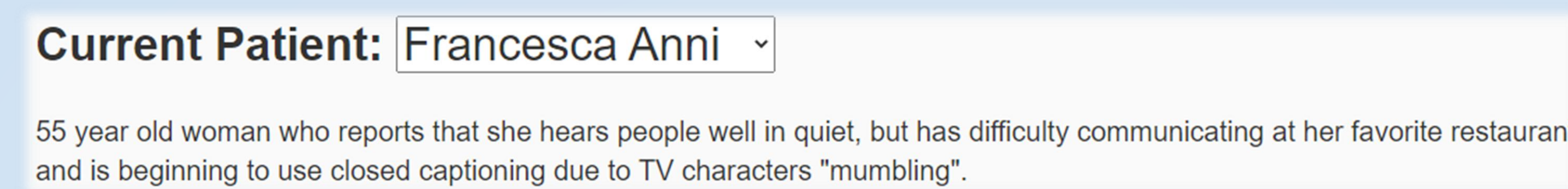


Figure 2: Example of qualitative informational component of patient profile

AvatarAudiometer also contains just over 5,400 additional sets of air-conduction-only thresholds which have been selected out of the CDC's NHANES database¹ in proportion to the United States' population distribution in terms of age and sex. These profiles may be used for larger-scale hearing screening practice.

RESPONSE SIMULATION

The decision made by AvatarAudiometer about whether or not to turn on the response indicator is based on a number of factors—including an element of chance to account for inherent human unpredictability. A curve is defined to translate a tone's volume relative to the patient's threshold to the probability that a patient will respond. For example, a patient might have a 50% chance of responding to a tone played at exactly their threshold, an 95% chance of responding to a tone played 5dB above their threshold, and a 5% chance of responding to a tone played 5dB below their threshold. These values can be changed depending on whether a simulation is desired to be simple or realistic in terms of difficulty to obtain accurate thresholds.

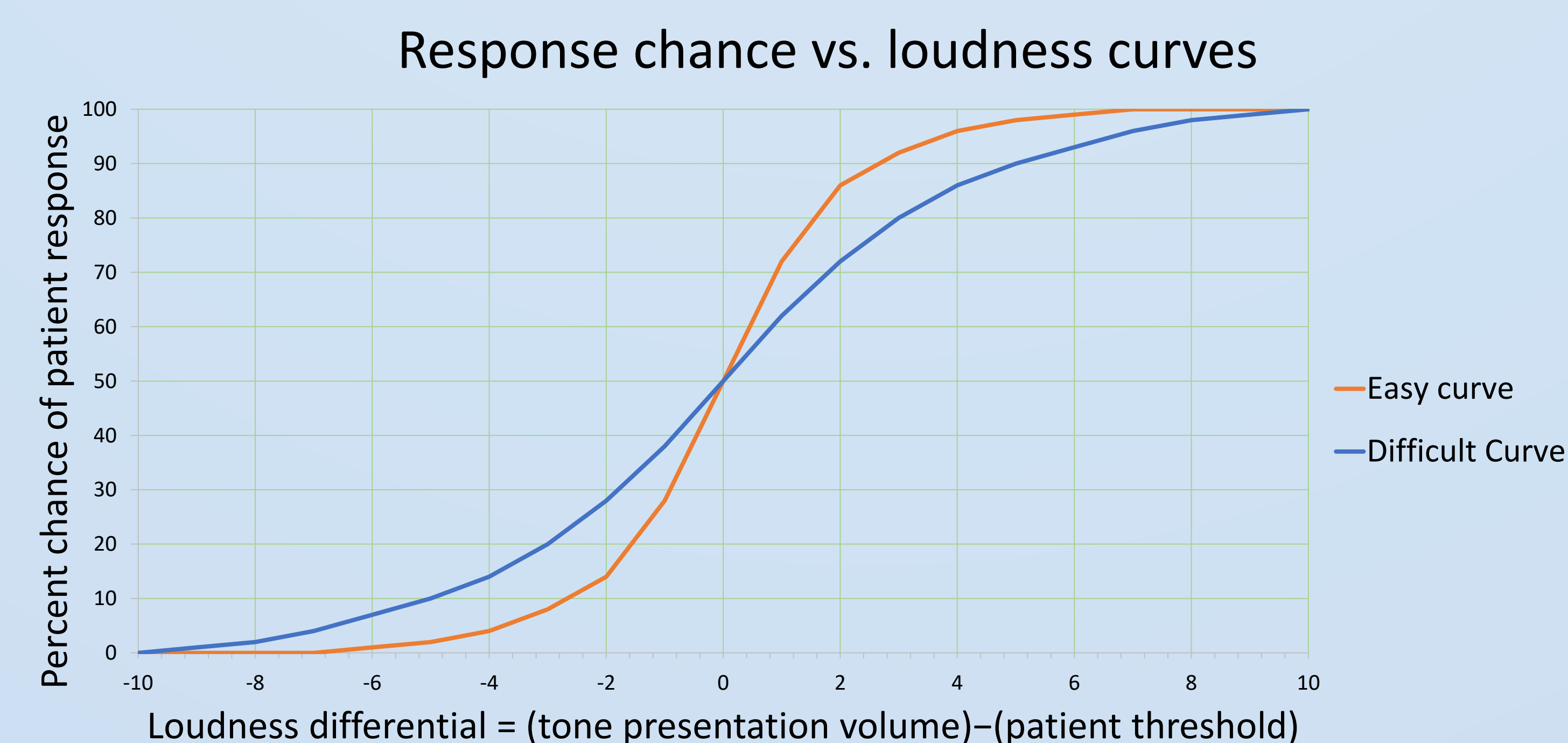


Figure 3: Potential response probability curves for virtual patients. The flatter the curve, the more likely patients are to give false or misleading response indications.

Randomness is also incorporated with respect to setting the time it takes for the patient to react to a tone. While different patients have different average reaction times, the specific time between a given tone presentation and patient response varies for a single patient too.

USAGE

AvatarAudiometer has been used in CWRU's COSI 370: Introduction to Audiology undergraduate class as a series of virtual labs regarding performing comprehensive PTA and prevalence of hearing loss in the population. It will also be used by graduate SLP students for practice—and it meets the requirements set forth by AHSA for "Clinical Simulation" that can be used to meet certification requirements².

Surveyed students (n=16) gave very positive feedback about AvatarAudiometer, with 100% considering their experience good or very good, and 94% reporting that it helped them understand the process of performing hearing exams.

"It was overall a great activity for us to use throughout the semester. I would not understand the concept of diagnostic hearing screenings if I didn't have the avatar audiometer in front of me."

"I like how interactive it is, in that it feels like I am actually using an actual audiometer."

"I like how I can practice this. It has made me more confident about what to do in a clinical setting."

"It's letting me practice administering hearing tests hands-on. This definitely helps me to better understand how these tests work since I'm a hands-on learner."

Figure 4: Selected survey responses from COSI 370 students.

FURTHER WORK

- Support auditory masking to allow for confirmation of "type" of hearing loss when hearing is asymmetric across ears.
- Add in simulation of patients' tendency to pick up on timing patterns in ways that lead to additional false positive responses
- Perform a small-scale study of the performance of students who are using a physical audiometer for the first time after having used AvatarAudiometer to practice versus those who have only prepared by textbook or lecture
- Analyze event tracking data to perform investigations into things like increases of efficiency over time on the part of testers, or the adherence of students from the standard "up 5, down 10" protocol. Data from more users will be required to perform meaningful analysis

ACKNOWLEDGEMENTS

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REFERENCES

¹Centers for Disease Control and Prevention (CDC). National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Data. Hyattsville, MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, 2000-2016. Audiometry.

²Certification Standards for SLP: Clinical Simulation. (2020). Retrieved November 19, 2020, from <https://www.asha.org/certification/certification-standards-for-slp-clinical-simulation>