An Auditory Gaming Application: AudIQ

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Abstract—**One of the primary indicators of hearing loss is that hearing impaired listeners struggle to distinguish a desired sound from a noisy background. In these situations, normal-hearing (NH) listeners can benefit by attending to perceptual attributes of the target sound. Thus, training listeners on auditory cue discrimination could improve their ability to attend to a target source in situations with background sound, thus enhancing communication in a crowded noisy social setting, such as a restaurant. Here we built an auditory game, AudIQ. We chose to program a mobile phone application, AudIQ, as a user-friendly interface, to both train listeners and collect user data for research purposes. AudIQ aims to train users on three specific auditory cues: pitch discrimination, sound localization, and speech identification in noise.**

Keywords—Auditory Cue; Mobile Application; Hearing Loss; Adaptive Tracking; Pitch; Sound Localization

I. Introduction

Currently, 36 million Americans suffer from some form of documented hearing loss [1]. This number is expected to increase largely due to hearing damage from portable music devices. One of the primary problems with hearing loss is the inability to hear and understand speech in noisy environments [1]. However, at least under laboratory conditions, listeners can benefit from being aware of and deploying attention to auditory identity cues, including sound timbre, pitch or location (e.g., [2]). For instance, studies have shown that when attending to a direction the of a speech source, speech identification can improve compared to a situation where one does not attend to the direction of the desired sound (e.g., [3]).

Previous work shows that it is possible to improve auditory function in individuals with hearing loss through training them with games ([4]). However, the underlying principles that allow for cognitive enhancement to generalize are incompletely understood. Here, we propose a mobile phone application, AudIQ, intended to train a user's ability to discriminate auditory cues. This app will serve to train listeners on three specific auditory tasks: pitch discrimination, sound localization and speech identification in background noise. Furthermore, the app will enable research on auditory cue learning.

II. AudIQ: The Training System

A. Adaptive Tracking

AudIQ utilizes adaptive tracking to assess the player's perceptual threshold ([5]). Specifically, the algorithm increases the difficulty of the game if the user answers questions correctly while playing. However, if the user answered a question incorrectly, the difficulty of the game decreases. Specifically, the difficulty increases after every two consecutively correct answers and decreases in difficulty level for every incorrect answer. Currently, the game completes after eight reversals of increases and decrease in task difficulty.

The game gets easier when the user answers incorrectly, reducing potential frustration and keeping a user motivated to play. Conversely, the user will continue to receive challenging questions and be motivated to learn, as the difficulty level increases upon consecutive correct answers. Therefore, the algorithm makes the training mechanism more effective and also keeps the game entertaining.

B. Training Sections

AudIQ consists of three different training sections, described below. Pitch discrimination trains the user through a platform style game. Specifically, the user reports whether a sound changed from "low to high" or "high to low" pitch (Figure 1). In the sound localization section, the user has to determine if a sound is coming from the left or right (Figure 2). In the speech-in-noise section, the user identifies the words uttered by a female talker that is embedded in background sound (Figure 3).

III. Data Storage

A. Remote Database

An important feature of AudIQ is the communication between a remote database and the smart device module. This module involves sending user's login information, such as user email and password, and user practice data, which includes the questions the user got correct and incorrect, retrieving stored information. Moreover, sounds for the game are stored on the remote database and then fetched from the database when required by the user. Researchers can see a user's data to analyze for research purposes. Specifically, the data is stored in the remote database in structurally organized tables.

B. Internal Database

The internal database was created so that the game could be played in an offline mode, such as in an airplane or on the subway. If an internet connection is unavailable or a user loses her or his Wi-Fi connection during gameplay, the user's data is stored in the internal database. Once an internet connection is established, user data from the internal database is transferred to the remote database and then deleted from the internal database to keep memory use to a minimum on the mobile device. The table structures of the internal database and remote databases are the same to allow for proper population of the data into remote storage.

IV. Sound Generation

Sounds are generated to be used in the game. These sounds are essential because they are used to train the user in each specific category. The properties recorded for each sound are duration, frequency, amplitude, interaural time difference (ITD), signal to noise ratio (SNR) and sampling rate.

A. *Generation of Pitch Sounds*

For the pitch discrimination section, the property of the sounds that is being altered is frequency. To train the user, two sounds of different frequencies are compared to each other and the user determines if the latter sound is higher or lower in pitch. Difficulty level increases as the difference in frequency between the two sounds decreases, ranging from 0.1 Hz to 1 kHz.

B. *Generation of Sound Localization*

For the sound localization section, the property of the sounds that is being altered is the interaural time difference (ITD), which is the difference in arrival time of the signals reaching the two ears (i.e., the time delay between left and right channel). To train the user, a sound is played and the user determines if the sound is coming from the left or the right. Difficulty level increases as the ITD decreases, ranging from 5 µs to 500 µs.

C. *Generation of Speech-In-Noise*

For the speech-in-noise section, the property of the sounds that is being altered is the broadband signal-to-noise energy ratio (SNR). To train the user, a single-word sound is played and the user identifies the speech content of that word. Difficulty level increases as the SNR decreases.

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Pitch Discrimination Game

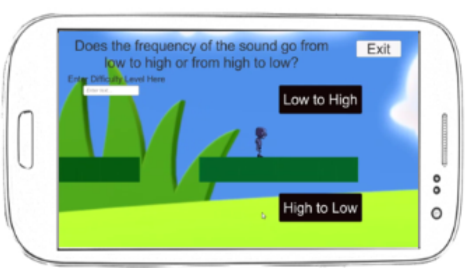

Figure 1

Sound Localization Game

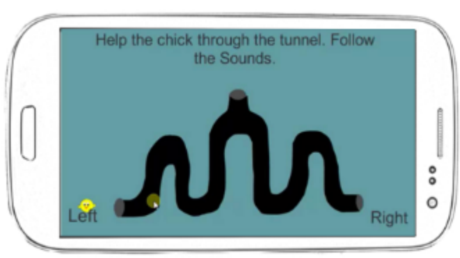

Figure 2

Speech-In-Noise Game

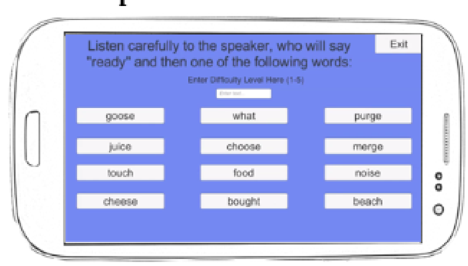

Figure 3