A NEW IPAD APPLICATION FOR HEARING SCREENING IN CHILDREN

Nicolas Ellaham[1], Yirgu Yilma[2], Guy-Vincent Jourdan[1], and Matthew Bromwich[3]
[1] School of Electrical Engineering and Computer Science, University of Ottawa, 800 King Edward av, ON, Canada, K1N6N5
[2] Epsidon Inc., 36 David dr, Ottawa, ON, Canada, K2G2N1
[3] Div. of Pediatric Otol. Head & Neck Surgery, Children's Hospital of Eastern Ontario, 401 Smyth rd, ON, Canada, K1H8L1
Email: nellaham@uottawa.ca, yyilma@gmail.com, gvj@site.uottawa.ca, mbromwich@cheo.on.ca

1. INTRODUCTION

Hearing plays a critical role in the development of speech and communication skills in children **Error! Reference source not found.**. Undiagnosed hearing impairment in childhood interferes with normal social, emotional and cognitive development.**Error! Reference source not found.**. A battery of physiological and behavioural tests has been designed specifically for testing children for hearing loss. Physiological tests that measure auditory function include: tympanometry, acoustic reflexes, otoacoustic emissions, and auditory brainstem response. Behavioural tests achieve threshold measurements by observing the child's behaviour in response to sound stimuli. Such tests have been developed for different age groups and include: behavioural observation audiometry (BOA, zero to five months), visual reinforcement audiometry (VRA, six months to two years), conditioned play audiometry (CPA, two to five years) as well as conventional audiometry (five years and over) **Error! Reference source not found.**.

Conditioned play audiometry is a standard way to test the hearing of children who are still too young for a convention audiometry test. During CPA testing, instead of simply raising one's hand in response to a sound, the child is engaged in a listening game: for example, hold a toy and wait for the sound, then drop the toy in a bucket when the sound is heard. The game is intended to keep the child interested in the listening task for the duration of the test. A CPA test consists of a familiarization phase followed by the actual hearing test. During the first phase, the audiologist or operator running the test establishes the child's interest in the game by teaching them how to play, and offering praise and rewards to reinforce correct responses. CPA tests are ideally conducted with the child (and possibly the parent) seated in a sound booth. However, screening tests using CPA are often performed in pre-schools, in a relatively quiet room, in order to identify children at risk of hearing loss.

Apple's iPad, and other tablet platforms in general, present a valuable medium to perform interactive tasks such as CPA. The iPad has quickly become a popular toy among children. The intuitive nature of the interaction with the iPad enables children as young as 2 years old to tap, swipe, draw, play and learn using an array of apps. In addition, there are now several apps that perform hearing tests using standard pure-tone audiometry.

In this work, we present a new app developed for the iPad to perform CPA as a hearing loss screening tool for pre-school children, ages 3 to 5. To the best of our knowledge, no app exists at the time of this writing, which is dedicated to the target age-group for CPA. The remainder of this article will give an overview of the system and discuss important considerations relevant to the design and use of the app.

2. APPLICATION OVERVIEW

2.1. Design and usage specifications

The app aims to engage children in game play where calibrated audio cues are essential to the interaction. As such, the app creates a virtual CPA test. In the familiarization phase, the child is taught to play an interactive listening game that involves touching items on the iPad screen that make sound. This phase can continue until the child understands the task and develops an interest in the game. During the testing phase the child plays the same game, while carefully-chosen sound stimuli are used to determine the hearing thresholds at four audiometric frequencies: 500, 1000, 2000, and 4000 Hz. For each frequency, the stimulus is presented at decreasing sound levels, until the child is no longer able to detect sound when touching the iPad screen, indicating that the hearing threshold at that specific frequency was reached.

In its first iteration, the app has been developed to conduct CPA screening in free-field environments. Audiometric tests are usually conducted with sound stimuli presented through earphones to obtain ear-specific information. For infants and young children who may not tolerate earphones, it is often more suitable to conduct tests using loudspeakers (free-field audiometry). However, aside from lacking ear-specificity, free-field audiometry presents other limitations imposed by room acoustics, background noise, listener head movement, and the type of sound stimulus used. Therefore, using the app for screening purposes requires an awareness of these limitations as outlined by the American Speech-Language Hearing Association (ASHA) [4]. For example, when access to a sound booth is not available, care must be taken in choosing the room where the screening is conducted; setting up the loudspeakers and listener locations. The app has been designed with these considerations in mind (cf. Section 3).

2.2. Screening results

The goal is to use the app as a screening tool, and not as a complete hearing assessment tool. Therefore, the final aim

is not a precise audiogram but a pass-refer decision. Once all four audiometric frequencies have been tested, the thresholds measured at each frequency in free field represent the child's binaural hearing thresholds. Along with the thresholds, the app also indicates the level of the ambient noise during the test. The app, therefore, assists the operator in determining the validity of the test. Children with elevated thresholds can then be referred to a specialist.

3. DESIGN CONSIDERATIONS

3.1. Free-field considerations

Under earphone listening conditions, audiometric tests are performed using pure tone signals. In free field, these signals create standing waves which result in a non-uniform sound intensity across the sound field. This, coupled with unpredictable listener movements, makes pure tone signals not suitable for use in this app. The ASHA guidelines [4] recommend using frequency-modulated (FM) tones with carrier frequency, modulation rate and bandwidth detailed by Walker (1984) [5]. Particularly, specifications for wide bandwidth were chosen for the stimuli used in this app, thus favouring sound-field uniformity over audiometric accuracy.

The app also provides a means to monitor the background noise in the room using an external microphone (the use of the iPad's internal microphone was avoided since it is more susceptible to disturbance from the child's body movement and touching the iPad screen). Monitoring the background noise during the screening test is important in free-field measurements, especially when dealing with (potentially noisy) young children.

3.2. Technical limitations of the iPad

The iPad houses a built-in speaker and microphone. A headset, including an earphone and microphone, is available as an accessory (and is also included with the iPhone). The popular headset connects to the audio port through a TRRS connector, and the microphone's flat frequency response makes it suitable for high-quality sound recordings. For this app, using the external microphone to monitor background noise and the built-in speakers to play sounds would be an appropriate scenario. In the Cocoa framework, the Audio Toolbox application programming interface (API), used to read and write audio, provides a means for redirecting audio routes to select either the built-in microphone and speaker, or the external headset. The API, however, does not permit using the built-in route for output and the external route for input. One solution consists of using third-party accessories, like TouchMic's Handsfree Lapel Microphone & Adapter, to connect an external microphone and loudspeakers to the audio port. An added benefit of this solution is the ability to move the loudspeakers around to make optimal use of the room acoustics. It is however possible to use an external USB microphone with the built-in speaker using an iPad USB adaptor.

3.3. Device calibration

Calibrating an audio system is essential before it is used to perform any scientific measurement and is recommended to be done periodically. The calibration of an audiometric system requires the use of expensive sound level meters and octave band analyzers and should be performed under the same acoustic conditions in which the device is used during measurements [6]. Since the aim of this work, is precisely to produce a portable system (iPad with the loudspeakers and microphone) for use where such equipment is not available, the app provides a means to carry out a two-step calibration. First, a standard "absolute calibration" is performed in which the system is calibrated in a controlled acoustical environment to conduct free-field measurements at each of the four audiometric frequencies used. The next step is an "on-site calibration" performed at the site where screening will take place, with the loudspeakers set up in position and the microphone placed where the subject's head would be. In this step the app auto-calibrates for each frequency at different presentation levels: for each level, the app plays the FM tones and adjusts the output signal level such that the microphone reading corresponds to the intended level.

4. SUMMARY

This paper presented a new app developed for the iPad platform to perform CPA tests for screening pre-school children for potential hearing loss. The app is intended for use in free-field environments where access to sound booths and elaborate equipment is not available. Equipment and environment limitations were discussed along with elegant solutions. A means of calibrating the system in two stages is also provided. A prototype of the app has been developed and is presently being tested in trials at the Division of Pediatric Otolaryngology, Head and Neck Surgery at the Children's Hospital of Eastern Ontario.

REFERENCES

[1] Canadian Association of Speech-Language Pathologists and Audiologists (2000), "Hearing health for children: Fact sheet", available from: http://www.speechandhearing.ca/files/children_hearing_fact_sheet.pdf. Accessed: July, 21, 2011.

[2] American Speech-Language-Hearing Association (1997), "Guidelines for Audiologic Screening" [Guidelines], available from: www.asha.org/policy. Accessed: July, 21, 2011

[3] Buttross, S.L., Gearhart, J.G., and Peck, J.E. (1995), "Early identification and management of hearing impairment", American Family Physician, 51(6), 1437–1447.

[4] American Speech-Language-Hearing Association (1991), "Sound Field Measurement Tutorial" [Relevant Paper], available from: www.asha.org/policy. Accessed: July, 21, 2011

[5] Walker G., Dillon H. and Byrne D. (1984), "Sound field audiometry: Recommended stimuli and procedures", Ear and Hearing, 5, 13–21.

[6] American National Standards Institute (1996), *Specification for audiometers* (ANSI S3.6-1996 (R2004)), New York: Acoustical Society of America.