DEVELOPMENT OF A LABORATORY LOCALIZATION TRAINING PROGRAM

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INTRODUCTION

Successful localization of a sound source is achieved through binaural processing of spectral, intensity and temporal cues of sounds. Listeners with hearing impairment may struggle with successful sound localization, partially due to reduced audibility of incoming sounds [Byrne and Noble, 1998; Lorenzi et al, 1999]. However, difficulties with localization may still persist, even if audibility has been restored with amplification. Spectral and intensity properties of sounds can be altered by the hearing aid, making it difficult for the listener to extract information on spatial location of sounds from the unfamiliar cues now received. Although the main goal of the hearing aid fitting is to improve communication, improving localization abilities can also be beneficial. The ability to accurately localize sound may help create a more natural perception of incoming sounds for the hearing aid wearer and maybe related to speech in noise understanding abilities.

SOFTWARE DEVELOPMENT

A localization training program was developed with the goal of improving localization abilities in hearing-impaired listeners using amplification. The training program presented three stimuli in random order:

- Female Speech ["Please choose the sound from this speaker."]
- Telephone Ring
- High Pass Noise [2kHz cutoff frequency]

The female speech and telephone stimuli were also high-pass filtered above 2 kHz, in order to prevent the listeners from utilizing low-frequency interaural timing cues to aid in localization. The three stimuli were presented from 12 loudspeakers surrounding the listener with 30° separation. Each stimulus was presented from each loudspeaker three times, for a total presentation of 108 stimuli per trial. The aided listener was situated facing the 0° azimuth loudspeaker at all times, with a distance of 1 meter from all loudspeakers.

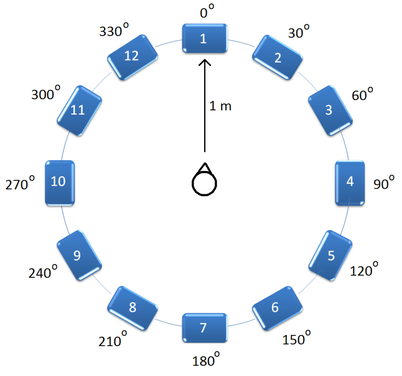


Figure 1. Loudspeaker arrangement for 360 degree localization training.

SOFTWARE DEVELOPMENT

Adaptive Algorithm for Test Difficulty

The difficulty level of the training program was adaptive, which allowed the program to be appropriate for all listeners with varying skills in localization. After training with the program twice, the program would average the previous two results and adjust the difficulty of the next two training trials. The training program increased in difficulty at a pace consistent with each individual's abilities. This ensured the same training program could be used with all hearing impaired listeners with varying localization abilities.

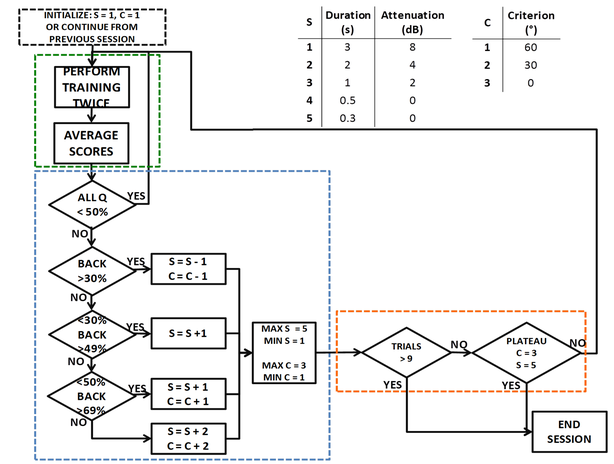
Stimuli Difficulty

Two adjustments to the stimuli could change the difficulty of the training program:

- The length of the stimuli could be adjusted between 3 and 0.3 seconds
- The level attenuation of the stimuli from the "back plane" of the 360 degree loudspeaker circle (120, 150, 180, 210, and 240 degree loudspeakers) could be adjusted between 0 and -8 dB

Scoring Difficulty

The criterion used for scoring a training session could also be adjusted to be more or less stringent depending on the current difficulty level. One of three scoring criterions [0, 30, or 60 degree] were used. A 0 degree scoring criterion meant that a response was counted as correct only if the correct loudspeaker was chosen. A 30 or 60 degree scoring criterion counted a response as correct even if the selected loudspeaker was incorrect as long as it was within 30 or 60 degrees of the correct loudspeaker.



S	Duration (s)	Attenuation (dB)
1	3	8
2	2	4
3	1	2
4	0.5	0
5	0.3	0

C	Criterion (°)
1	60
2	30
3	0

Figure 2. Adaptive algorithm for chosing the difficulty level of localization testing based on a user's localization ability.

GRAPHICAL USER INTERFACE

After a stimulus is presented, the listener uses a touchscreen interface to indicate which loudspeaker they thought the stimulus originated from. The program was designed to provide immediate feedback to the listener regarding their ability to localize. If the listener indicated an incorrect loudspeaker as the origin of the sound, the correct location is highlighted on the touchscreen (green color), along with the incorrect location chosen by the listener (red color).

After incorrectly selecting the origin of the sound, the listener is then able to re-listen to the stimulus from both the correct and incorrect loudspeaker in order to compare how the stimulus sounded when coming from each of the two locations. The listener is able compare each sound as many times as desired before moving on to the next stimulus.

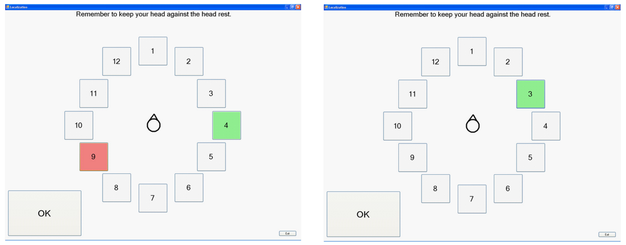


Figure 3. Touch screen graphical user interface for listener repsonses. If an incorrect loudspeaker is selected [left], the correct loudspeaker will turn green and the incorrect loudspeaker will turn red. If a correct loudspeaker is selected [right], the loudspeaer will turn green.

After all stimuli has been presented from each loudspeaker 3 times, the test will conclude and separate results screens will be displayed to the listener and the test administrator. The listener is able to see a graphical representation of their performance for each loudspeaker. A range of colors from red to green helps to provide intuitive feedback for the user after completion of the training program. The listener is able to visually identify particular regions where they may have difficulty localizing. The displayed performance is calculated based on the current difficulty level scoring criterion.

Figure 4. Results displayed at the conclusion of training: A graphical display is provided for the listener [left]. A numeric display for the test administrator [right].

METHODS

Data were collected from 15 listeners with mild to severe sensorineural hearing loss that completed the localization training program. The localization abilities of the listeners were tested before, during and after the program was performed. The listeners performed the program in multiple 2-hour sessions over a one month period.

RESULTS

After one month of multiple 2-hour training sessions, the localization performance of the listeners back quadrant scores improved by 30% compared to their performance prior to using the laboratory localization training program.

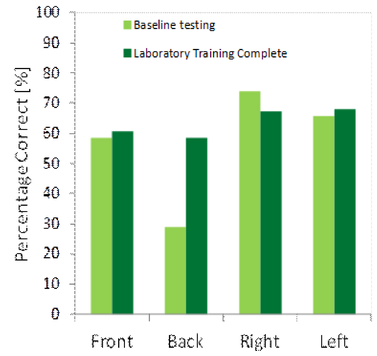


Figure 5. Average results for 300ms test stimuli and no back loudspeaker attenuation at baseline testing and after one month of laboratory training.

CONCLUSIONS

The results suggest that the program useful in allowing hearing impaired listeners to to improve some localization abilities. This program may be particularly useful in helping hearing impaired listeners to reduce the number of front/back localization errors.

REFERENCES

Byrne, D// Noble, W. 1998. Optimizing sound localization with hearing aids. Trends Amplif, 3:51-73.
Lorenzi, C// Gatehouse, S// Lever, C. 1999. Sound localization in noise in hearing-impaired listeners. J Acoust Soc Am