Localization in Bilateral Hearing Aid Users

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INTRODUCTION

This study with bilateral hearing aid (HA) users was designed to help us understand the localization abilities of cochlear implant (CI) patients with hearing preservation (see, for example, Dunn et al., 2010). Hearing preservation patients have low-frequency hearing in both the implanted ear and in the contralateral ear and, most commonly, use hearing aids in both ears. To have a reference for the localization performance of these patients and their access to interaural timing difference cues (ITDs) we tested the localization ability of bilateral HA patients using low frequency (LF) – under 500 Hz—noise bands. The research questions were:

- **Do hearing impaired listeners show sensitivity to ITD cues – as measured by localization performance using LF stimuli**
- **Do bilateral hearing aids alter localization ability?**

BACKGROUND

Lorenzi et al. (1999) reported that hearing-impaired listeners have poorer localization abilities than normal-hearing listeners. Aiding hearing-impaired listeners has been shown (i) to improve performance (Boymans et al., 2008), (ii) to depress performance (van den Bogaert et al., 2006) and (iii) to have no effect at all on performance (Kobler and Rosenhall, 2002). Clearly, more work needs to be done.

METHODS

Young (ages 21-40 years) and Mature (ages 50 – 70 years) NH listeners were tested and are used as a reference on localization for the hearing impaired (HI) listeners. Root mean square (RMS) error in degrees was calculated for both groups of NH listeners. At issue was whether age influenced localization ability.

__Bilateral Hearing Aid Users__ (Table 1)

Ten bilateral HA users with symmetrical mild to severe sensorineural hearing loss (Fig. 1) were tested, unaided and aided, on a test of localization. The HAs were electro-acoustically analyzed to determine the phase relationships of the microphones. This was assessed to eliminate the possibility of out-of-phase HA causing potential localization difficulties. All pairs of HAs were in-phase. Subjects were tested with their current user settings.

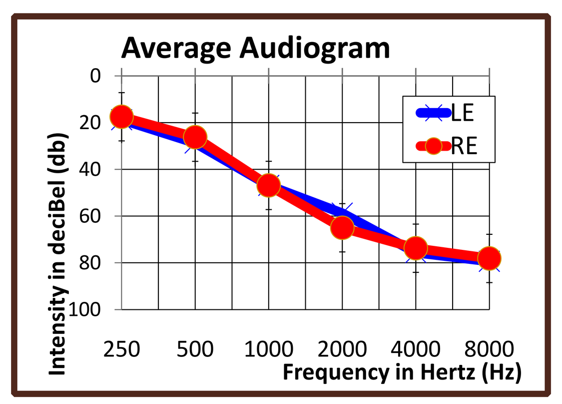

FIGURE 1. Averaged audiogram for all hearing aid users.

Subject	Age	Gender	HA make/model
1	86	F	Oticon/ BTE
2	69	F	Widex/ BTE
3	71	M	Widex/ BTE
4	72	M	Widex BTE
5	74	M	Oticon/BTE
6	49	F	Phonak/ BTE
7	80	F	Widex/ BTE
8	61	F	Phonak/Canal
9	67	M	Widex/CIC
10	77	F	Oticon/BTE

TABLE 1. Demographic data for HA users.

METHODS con't

__Stimuli__

Three, 200-msec, filtered (48 dB/octave) noise stimuli with different spectral content were presented in random order. Noise stimuli consisted of:

- low-pass (LP) noise filtered from 125-500Hz
- high-pass (HP) noise filtered from 1500-6000 Hz
- wideband (WB) noise filtered from 125-6000 Hz

Here we are reporting on performance of subjects to the LP stimuli. Presentation of the stimuli was controlled by Matlab and presented from a 13 loudspeaker array with an arc of 180° in the frontal horizontal plane (Fig. 2). Four blocks of 33 trials each were presented at 65 dBA; level was adjusted in 5dB increments as necessary to make it audible in the unaided conditions. Overall level was randomly roved 2 dB from presentation to presentation to ensure that the level of the loud speakers was not a cue. Testing was alternated between aided and unaided listening conditions with half of the subjects tested in the aided condition first and the other half tested first in the unaided condition. Subjects were instructed to look at the midline (center speaker) until a stimulus was presented. They were then free to look and determine which speaker presented the stimulus. They entered the number of the speaker on a keypad.

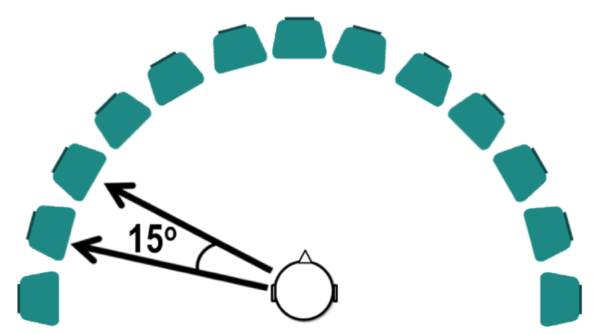

FIGURE 2. Loud speaker array spanning 180° in the horizontal plane. Speakers are spaced 15 degrees apart.

RESULTS

Root mean square (RMS) error in degrees was calculated for localization to LP stimuli for Young and Mature NH listeners (Fig. 3).

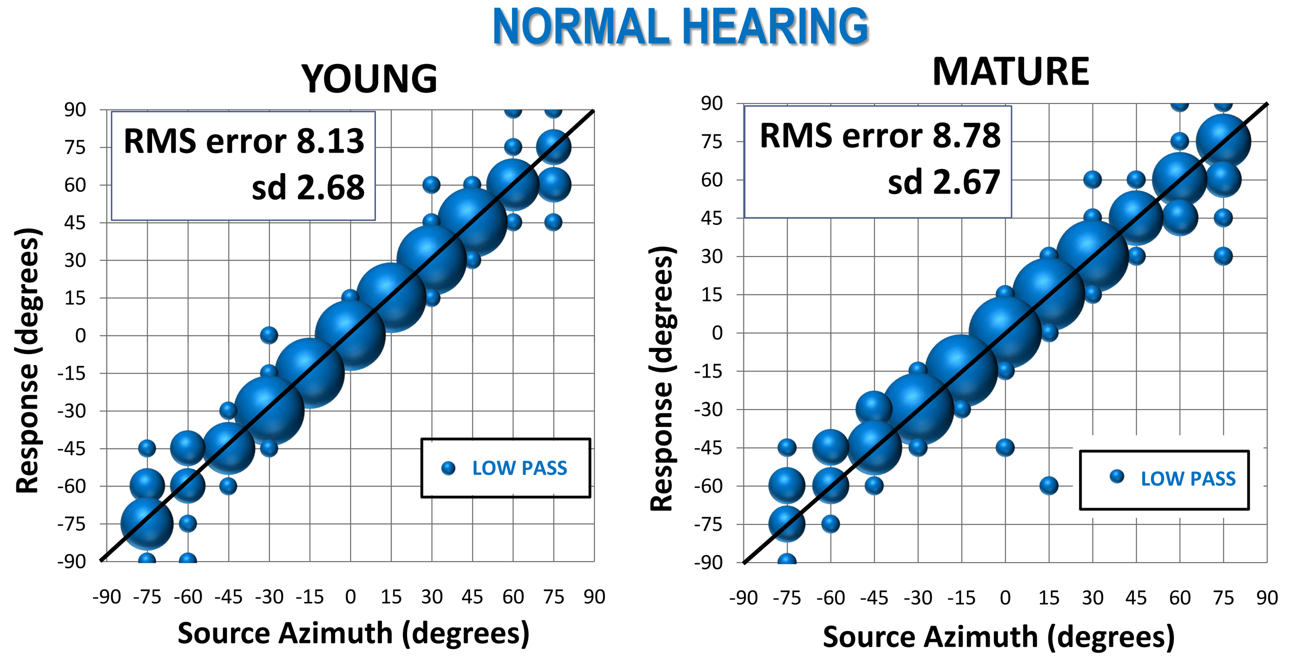

FIGURE 3. Location responses of Young and Mature NH listeners.

RESULTS con't

Results show no differences in RMS error between the NH groups. Degrees of error for the Young NH were 8° and degrees of error for the Mature NH were 9°.

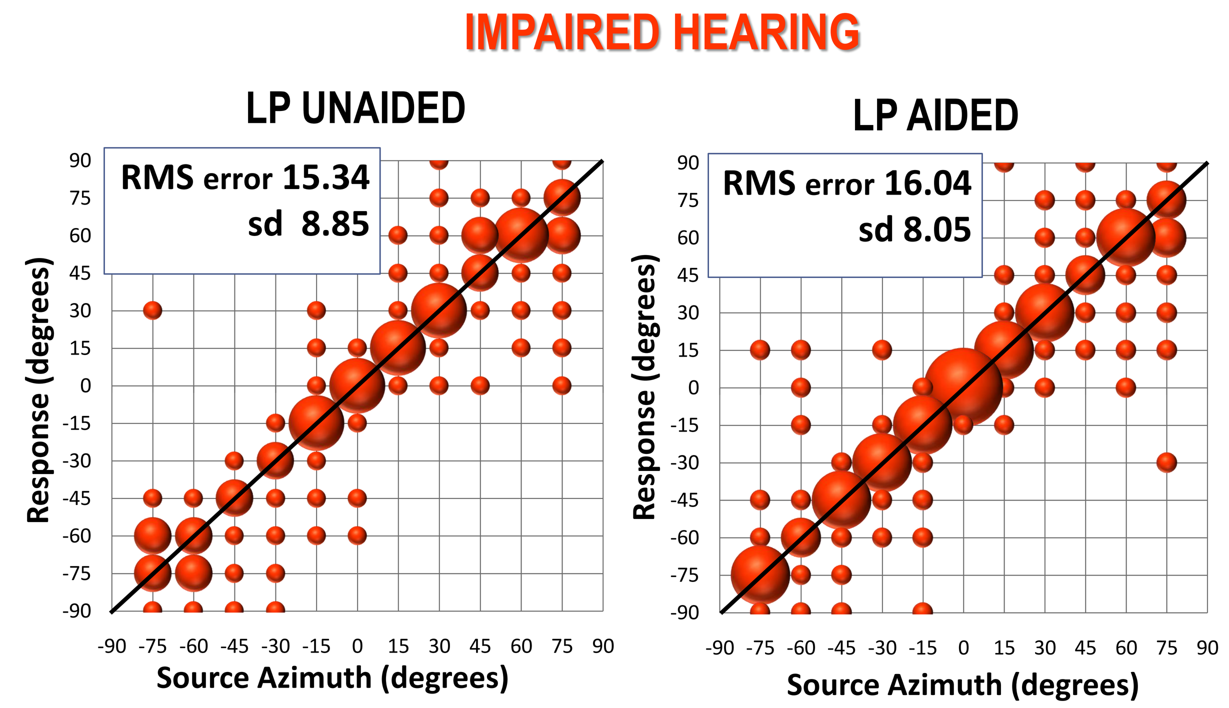

FIGURE 4. Unaided and aided location responses as a function of source location for low pass sounds.

Errors for the HI group were larger than NH listeners in both the unaided and aided conditions. The RMS error for the unaided was 15°. RMS error for the aided was 16°. Errors are more scattered as the responses move away from the center source, 0° azimuth. Average RMS errors are not different between unaided and aided conditions for the HI group, t (9)= .68 , p<.05 but are significantly different between the NH and unaided HI group, t(30) = 3.54. p<.001.

Individual responses for each HI subject compared to NH listeners show a range of responses from normal to impaired (Fig. 5).

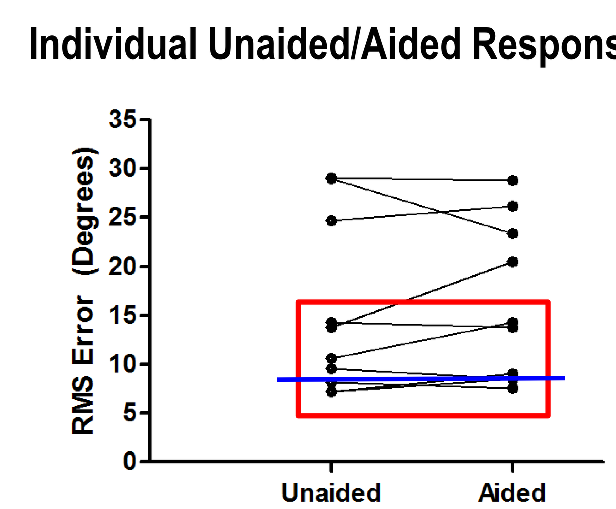

Figure 5. RMS error as a function of unaided and aided responses to LP stimuli. Range of RMS error for normal hearing listeners is shown in red rectangle. Mean RMS error for NH is shown as a blue line.

Our results show:

- **some bilateral HA users demonstrate localization abilities comparable to NH listeners for LP stimuli**
- **some bilateral HA users have errors two-three times those of NH listeners for LP stimuli**
- **amplification has no effect on localization for most of the bilateral HA users**

RESULTS con't

Some HA users have normal access to ITD cues while others do not. This did not correspond to audiometric thresholds. One subject with the poorest thresholds at .25k and .5kHz localized as well as NH listeners, 7°, to LP stimuli. Another subject with the best thresholds at .25k and .5kHz had impaired localization to LP stimuli with RMS errors of 25°.

Localization to LP stimuli appears to be determined by unaided localization abilities. In other words if listeners are able to access ITD cues without HA then aided localization will not deteriorate. If, on the other hand, HA users are already impaired on localization then HA will not restore their ability to use timing cues. We cannot account for differences in localization based on the signal processing in the hearing aids since users of all three manufacturers demonstrated both normal and impaired localization.

Unlike van den Bogaert et al., (2006) we did not show deterioration in the aided condition compared to the unaided condition. We also did not show improvement in the aided condition reported by Boymans et al., (2008). Our results are most consistent with Kobler and Rosenhall (2002) who showed that hearing aids neither hinder nor improve localization for HI listeners.

IMPLICATIONS

Based on our results with bilateral HA patients responding to LF noise bands, we can expect hearing preservation patients to show a range of localization abilities -- from near normal to very abnormal. However, all should be able to at least **lateralize** stimuli. It is likely that localization ability will not be related to audiometric configuration. In this sense, localization may be like speech understanding in that the benefit of adding acoustic to electric stimulation is not related, in simple fashion, to the magnitude of the hearing loss.

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