Differences in Localization Ability in Cases of Right versus Left Unilateral Simulated Conductive Hearing Loss

Tori J. S. Gustafson*
Teri A. Hamill

Abstract
The purpose of this study was to determine whether localization errors were greater in cases of right ear unilateral simulated conductive loss, as compared to left ear simulated conductive loss of the same degree and configuration. Thirty adults were asked to localize a 3-kHz warbled pure tone with their left and right ears alternately occluded with an earplug. Significantly greater localization difficulty was found when the right ear was occluded. The average error was 58 degrees with the left ear plugged and 64 degrees when the right ear was occluded, which approximates the 65-degree average error that would have resulted from random guessing. This suggests that short-term conductive losses result in unusually poor localization ability, which is worse if the right ear is affected.

Key Words: Conductive loss, localization, right/left differences, unilateral hearing loss
effects, while difficulties in cases of sensorineural hearing loss were due to distorted spectral processing.

Bess and his colleagues (1986) found that, in subjects with sensorineural hearing impairment, localization of a 3-kHz tone was poorer for cases of right unilateral hearing impairment. However, no significant left/right ear differences were noted at 500 Hz. Bess et al (1986) compared the localization ability of subjects with left versus right unilateral sensorineural hearing loss. A study with such a design could not directly compare left and right hearing loss conditions due to intersubject differences. In the present study, we questioned whether this decreased localization ability, when the right ear is impaired, is a result of removing the ability to use a right-ear advantage for localization. We hypothesized that, if this were the case, those with short-term conductive losses would also exhibit greater difficulty in localizing with a hearing loss in the right ear. To accurately address the issue of differences in localization ability in the case of right versus left unilateral hearing loss, we compared a single subject’s localization ability in a right unilateral simulated conductive hearing loss condition to his/her localization ability with a left unilateral simulated conductive hearing loss of the same degree and configuration.

METHOD

Subjects

Thirty subjects with hearing thresholds at or below 20 dB HL at 0.5, 1, 2, 3, and 4 kHz in each ear were tested. Volunteers were excluded from participation if their hearing thresholds varied between ears by 10 dB or more at two or more frequencies or by 15 dB or more at any one test frequency. Twenty-six of the subjects were female. The average age was 20.6 years (range = 18 to 24 years). Three of the 30 subjects reported a preference toward left-hand use as indicated by results of the handedness survey developed by Annett (1970).

Apparatus

One-second duration, 3-kHz warbled tones were used as the test stimuli. The tones were produced by a Grason-Stadler 16 audiometer, which created a ± 5 percent frequency deviation at a rate of 5 warbles/second. The tones were routed to Realistic 4-inch midrange speakers. These speakers are designed to have a relatively flat frequency response (± 1 dB) in the 1 to 10-kHz range. Thirteen such speakers were located in a semicircle around the subject’s chair. Each speaker was situated 119.4 cm from the floor and 89 cm from the center of the chair. The speakers were separated by 15 degrees of angle and were numbered 1 through 13. The speakers were calibrated to produce a 55-dB HL (± 0.5 dB) warble tone (65 dB SPL) using a Quest 155 sound level meter and Larson-Davis 2575 microphone.

The test room was an IAC booth (193 cm × 213 cm × 194 cm), which has absorption coefficients of at least 1.03 (Industrial Acoustics Company, 1986). The floor rubber mat’s absorption coefficient was approximately .02 and .03 for 2 and 4 kHz (Bruce and Toothman, 1986). The room had an examiner’s window and a mirror, with absorption coefficients of approximately .07 and .04 at 2 and 4 kHz, respectively. The calculated reverberation time (Bose Modeler Design Program Version 4.1) was .287 msec at 500 Hz and .263 msec at 1 kHz.

Procedures

Each subject was tested with both a simulated right and a simulated left unilateral loss. The loss was created by the insertion of an EAR plug (Cabot Corporation, Indianapolis, IN) into the ear. Care was taken to use the same insertion depth in each ear. The ear chosen to be tested first was counterbalanced to minimize the influence of learning effects.

Prior to localization testing, each subject received threshold testing with the earplug in place in order to assure that equal degrees of hearing impairment were created in each ear. The degree of loss did not vary between ears by more than 10 dB at any one frequency, nor was there more than 5 dB of difference between ears at 3 kHz.

With the plug in the test ear, localization ability was assessed. The subject was instructed to look straight ahead (at speaker #7) while the stimulus was presented, then to indicate from which speaker the tone originated. Tones were presented from each speaker five times, resulting in a total of 65 test tones. The order of stimulus presentation was randomized.

Localization error was calculated using the error index method described by Gardner and Gardner (1973). In this method, the error index is the cumulative number of speakers in error divided by the error score attributable to guessing.
randomly. In this experiment, the average number of speakers off due to guessing would be 4.03. In 65 trials, the cumulative number of speakers off would be 280 due to random guessing. An error index of 0.0 would indicate perfect localization ability, while an index of 1.0 would represent random guessing behavior. It is possible to obtain an error index score greater than 1.0.

**RESULTS**

The mean error index score for the left simulated conductive loss condition was .90 (.24 SD), while it was .98 (.18SD) for the right simulated loss condition. Since both of these error indices approximate 1.0, localization ability was considered poor in both cases, although it was significantly worse for the right-ear-plugged loss (repeated measures t-test: $t = 2.79$, df = 29, $p < .009$). The error index scores greater than 1.0 obtained by some subjects indicate poorer localization ability than would be obtained by random guessing behavior.

Twenty-one subjects had a greater error index in the right-ear-plugged condition, while only nine people had a greater error index score in the left-ear-plugged condition. A Pearson product-moment correlation coefficient of .740 ($p < .001$) between the right-ear-plugged condition scores and the left-ear-plugged condition scores was obtained. This suggests that the subjects who did poorly in one condition tended to do poorly in the other condition as well.

The group data can also be analyzed by describing the average amount of error in angular units. In the left simulated loss case, the subjects' speaker identifications were, on average, 3.88 speakers away from the actual source, which converts to 58.2 degrees average error. For the right ear loss condition, the subjects averaged 4.23 speakers in error, or approximately 63.5 degrees. Thus, the ear impaired created a difference in localization ability of 5 degrees.

The right/left condition differences are also shown in Figure 1. Here, average error for the subjects is tabulated. The ordinate is the number of subjects with an error index score within the given range. The filled bars indicate performance in the right ear hearing loss condition, with the left ear condition indicated by the open bars. While having a right unilateral impairment, approximately 45.3 percent of the subjects had average errors less than 65 degrees, while 70 percent of the subjects had such scores with a left unilateral impairment. The average error scores of the three left-handed individuals were 1.09 and 1.08 in the right and left simulated loss conditions, respectively. The number of subjects is insufficient for comment on the effect of handedness on localization ability while having a simulated unilateral hearing loss.

Figure 2 summarizes the error patterns made by the subjects. The ordinate indicates the average differences between the subject-selected speaker and the actual presentation speaker. On the abscissa, the first number in the pair indicates the presentation speaker location when the right ear was occluded, while the second number indicates the speaker location during the left ear occluded condition. Thus, 1/13 represents the speakers that were at 90 degrees azimuth, facing the unplugged ear, while 13/1 are the speakers closest to the plugged ear. As shown, more error occurred when the sound originated from the speakers on the side of the head toward the occluded ear (8/6 to 13/1). There was a tendency for subjects to select speakers on the unplugged side of the head. When the sound was presented from speakers 8/6 to 13/1, there was a tendency for subjects to select speakers 1/13 to 3/11, which resulted in considerable error. For example, with the left ear plugged, when the tone was presented from the speaker located at 90 degrees azimuth on the left side, it was not uncommon for the subject to select the speaker located at 90 degrees azimuth on the right side (towards the unplugged ear).
This would result in the maximum amount of error possible (selected speaker is 12 speakers away from the actual source), which may explain the finding of error index scores greater than the 1.0 attributable to random guessing.

**DISCUSSION**

In this study, subjects had more difficulty localizing while experiencing a right simulated conductive impairment. In the study by Bess et al (1986), the average localization error index for subjects with sensorineural unilateral hearing loss was .78, which translates to 50 degrees of angle difference (left/right average error index scores were not reported). This contrasts with the .90 and .98 error indices for the left and right hearing loss conditions, respectively, in this study.

There are several possible explanations for the degree of difference between the error index scores for sensorineural versus simulated conductive hearing loss cases. While the experimental conditions differed slightly between the current study and that by Bess et al (1986), the greater localization difficulty found in this study may support the theory that localization ability improves with prolonged hearing loss and/or training, as has been suggested by the work of Bauer et al (1966) and Fisher and Freedman (1968). This may indicate that transient conductive losses may result in greater localization difficulties than do long-standing losses, and suggests that those with right unilateral hearing impairment will experience a greater degree of localization difficulty. Another possible explanation for the differences in index scores between studies may be related to the difference in the underlying cause of the localization difficulties. If two different mechanisms are responsible for the localization difficulties in sensorineural and conductive hearing loss, as proposed by Hausler et al (1983), this could also explain the error index differences. Given that the right versus left differences in localization ability are present in both types of loss, this may suggest that the cause of greater localization difficulties for subjects with right unilateral hearing loss is not related to the type of loss, although the degree of difficulty may be related to the type of loss or its duration.

The results from this study suggest areas for further research. It is possible that stimulus composition affects localization ability and it may be worthwhile to assess localization using stimuli that create a more uniform sound distribution. Walker and Dillon (1983) have recommended the use of wider percent modulation and faster warble rates to achieve this objective; however, the audiometer used in this study was not capable of producing these stimulus characteristics. Further testing using an anechoic chamber would strengthen the research by reducing any possible effects related to reverberation. Another area of interest would be to retest subjects to determine the test–retest variability. This could also serve to explore the theory that localization ability in cases of unilateral hearing loss improves with time, especially if losses were simulated for extended periods of time.

**REFERENCES**


