Virtual Midplane Localization in Subjects with Sensorineural Hearing Loss

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Abstract: In this study, simulated "real-world" localization performance of normal-hearing (NH) subjects and subjects with sensorineural-hearing loss (SNHL) were compared using simulated externalized signals presented with either Unbalanced [individual NAL-R for each ear] or Balanced [equal sound pressure level at both ears] binaural hearing aid gain. A simulated externalized auditory image was combined with head position control of IID and ITD to spatially fix the image. Although there were considerable individual differences, several trends are apparent. 1) At almost every center frequency, the NH listeners showed significantly less localization error than did the SNHL listeners. 2) Greater variability is evident for the SNHL subjects and the older NH subject. 3) For most center frequencies, the mean perceived azimuth was closer to 0° azimuth in the Unbalanced than in the Balanced condition. 4) In some subjects, the perceived azimuth remained more constant across frequency in the EqSPL condition, although this azimuth was not necessarily close to zero. These data will be discussed in terms of binaural hearing aids fitting strategies and individual differences that might be attributable to differential sensitivity to ambiguous time stimulus cues, differential task sensitivity, and the differential effects of adaptation, age, head movement, and threshold asymmetries.

INTRODUCTION

The purpose of the present study is twofold: 1) to test "aided" localization using a simulated externalized auditory image with SNHL subjects; and 2) to assess two methods of equating interaural stimulus amplitude, either Unbalanced [individual NAL-R for each ear] or Balanced [equal sound pressure level (EqSPL)] hearing aid gain at the two ears.

To ensure optimum performance from our subjects, we developed a procedure to simulate "real-world" localization in a controlled experimental environment. The two methods used to accomplish this consist of a virtual reality testing environment and a paradigm that keeps the stimulus in the frontal plane where it is easiest to localize [1]. Combined with this virtual environment was an additional stabilization technique, developed and implemented in our laboratory, which uses head-position control of IID and ITD to generate an auditory image stabilized in extracranial space. In a previous report from this laboratory (2), it was found that when equalizing by SL, the perceived lateral position was essentially linearly dependent on the degree and direction of asymmetry in normal-hearing (NH) and SNHL listeners. Equalizing by SPL showed no such dependency. It was hypothesized that the current practice of fitting "binaural" hearing aids in asymmetric SNHL listeners using prescription formulae might result in SPL imbalance which would disrupt the previously adapted system and impair localization. The present study was designed to address this issue by measuring localization under both unbalanced and equal SPL conditions.

METHODS

Real-world localization performance was measured using 1/3-octave band noise stimuli from 250 - 4000 Hz with an absolute judgment paradigm in which the subject pointed his/her nose to the perceived position of a virtual sound source. Individualized head-related transfer functions (HRTFs) for each subject were recorded in an anechoic sound-field environment and applied to the stimuli during the experiments. Acoustic image stabilization, via tracking of head position, kept the stimulus at a fixed location in external space, thus simulating the real-life situation in which a sound at a given point in space is altered by the subject's head-position-varying HRTF. Three normal-hearing and six sensorineural hearing loss subjects were tested. In the Unbalanced condition, SNHL subjects were tested with a hearing aid prescription based on the revised version of the National Acoustic Laboratories (NAL-R) (3) that was applied to the stimuli after the application of the HRTF. In the Balanced condition, the interaural level was equalized by presenting the stimuli at a level equidistant between the calculated gains in each ear (at those frequencies where threshold asymmetries resulted in unequal gain at the two ears.)
RESULTS

We obtained the mean absolute perceived azimuthal position of the stimulus which indicates the magnitude of the localization error without regard to direction. These results were confirmed by statistical analysis. A repeated measures analysis of variance (ANOVA) was carried out (using the Balanced data) to examine the effects of Group (SNHL vs NH) and Center frequency (13) on the mean absolute perceived position. Testing the hypothesis using a Type III Mean Square (MS) for Group (SNHL vs NH) as an error term showed a highly significant (a criterion level of p < .05) main effect of Center frequency and a significant interaction of Group*Center frequency. Collapsing across center frequency, mean scores for the three NH and six SNHL subjects (using the Balanced data only) were 6.6° (1.0) and 9.1° (2.1), respectively. The NH subjects showed less variability across center frequency than did the SNHL subjects. Tukey-Kramer post-hoc analyses for the interaction of Group*Center Frequency show significant pairwise comparisons between the NH and SNHL groups at most frequencies.

For the SNHL subjects, the results of balancing are further from center than those of the Unbalanced condition at eight of the 13 frequencies. Collapsing across subjects and center frequency, the mean absolute localization error in the Unbalanced condition was 8.6° (1.4) and 9.1° (2.1) in the Balanced condition. For most center frequencies, the mean perceived azimuth was closer to 0° azimuth in the Unbalanced than in the Balanced condition. There is also less variability in the Unbalanced than in the Balanced condition. However, in some subjects, the perceived azimuth remained more constant across frequency in the EqSPL condition, although this azimuth was not necessarily close to zero.

CONCLUSIONS

The mean localization differences between conditions (Balanced and Unbalanced) and groups (NH and SNHL), although statistically significant, were small and results may or may not be clinically significant. There were also large individual differences in localization as a result of balancing interaural gain by SPL. These individual differences might be attributable to differential sensitivity to ambiguous time stimulus cues, differential task sensitivity, and the differential effects of adaptation, age, head movement, and threshold asymmetries. It may be insufficient to balance or correct for asymmetric hearing loss via either EqSL or EqSPL. What may be needed is a binaural perceptual balance of intensity across frequencies. Further studies to test our balancing assumptions directly are currently being planned in this laboratory.

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REFERENCES