Do hearing-impaired listeners benefit from spatial and temporal cues in a complex auditory scene?

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ABSTRACT

In auditory scenes containing many similar sound sources, difficulties with the detection and organization of acoustic information can lead to disruptions in the identification of behaviorally relevant targets. A previous study conducted in young normal-hearing listeners (Best *et al.*, 2007) investigated the benefit of providing simple visual cues for when and/or where a target string of spoken digits would occur in a complex acoustic mixture. Importantly, the visual cues provided no information about the target *content*. A visual cue indicating which loudspeaker (from an array of five) would contain the target improved accuracy, and a cue indicating which time segment (out of a possible five) would contain the target resulted in a smaller improvement. The present study extended this work to young listeners with sensorineural hearing loss. These listeners performed more poorly overall than the normal-hearing group, but did benefit from visual cues indicating where and when to listen for the target. While the magnitude of the temporal cue benefit was comparable between groups, the spatial cue benefit was smaller on average for the hearing impaired-listeners. This result suggests that one component of the difficulties experienced by listeners with hearing loss in complex tasks of this nature is related to directing spatial attention.

INTRODUCTION

In many everyday listening situations, a listener’s goal is to hear out one sound of interest from amongst a mixture of other interfering sounds. Normal-hearing (NH) listeners are remarkably adept at this, and make use of many physical properties of the stimulus to accomplish this task. For example, when interfering sounds fluctuate over time, listeners are able to make use of brief “glimpses” of the target (Cooke *et al.*, 2006) and/or of comodulation across frequency in the interferers (Grose and Hall, 1992). When competing sound sources

sources (after Best *et al.*, 2007). Based on a substantial body of previous research, it was expected that HI listeners would perform worse overall on the task than NH listeners. For example, HI listeners receive little benefit from amplitude fluctuations present in interferers such as speech (Duquesnoy, 1983; Festen and Plomp, 1990; Bronkhorst and Plomp, 1992; Lorenzi *et al.*, 2005) and a greatly reduced benefit from spatial separation of simultaneous sources (Bronkhorst and Plomp, 1989; Marrone *et al.*, these proceedings). However, the effect of hearing impairment on the direction of attention within this kind of scene remains unclear. Listeners with hearing loss normally rely heavily on non-auditory cues (such as those provided by lip-reading) to function in difficult listening situations. For this reason these listeners might benefit *more* than NH listeners from visual cues about timing and location in the listening environment simulated here. On the other hand, reduced spectro-temporal resolution in HI listeners may limit the perceptual segregation of competing sources, which could make it difficult for them to direct spatial attention selectively to the target source (Shinn-Cunningham, these proceedings). If so, HI listeners might benefit *less* than NH listeners from visual cues that guide attention. The overall goal of the current study was thus to determine whether hearing impairment has an impact on improvements in speech intelligibility that are specifically related to attention.

METHODS

Listeners

Seven HI listeners (2 male, 5 female, aged 19 – 42) and eight normal-hearing listeners (3 male, 5 female, aged 19 – 30) participated in the experiment. Listeners were paid for their participation, and the experiment was approved by the Boston University Charles River Campus Institutional Review Board.

The HI listeners had mild to moderately severe, bilateral, symmetric, sloping, sensorineural

Environment

The experiments took place in a single-walled IAC booth with interior dimensions of 12’4” x 13’ x 7’6” (length, width, height), with perforated metal panels on the walls and ceiling and a carpeted floor. The listener was seated on a chair in the center of the room, with a head rest to minimize head movements. No instructions were given to listeners regarding eye fixation during stimulus delivery. Stimuli were presented via five loudspeakers (Acoustic Research 215PS) located on an arc approximately 5 ft from the listener at the level of the ears. The loudspeakers were positioned within the visual field at lateral angles of -30°, -15°, 0°, 15°, and 30°. Listeners indicated their response using a handheld keypad. The booth was kept dark during the experiment, except for a small lamp to illuminate the keypad.

Digital stimuli were generated on a PC located outside the booth and fed through five separate channels of Tucker-Davis Technologies hardware. Signals were converted at 40 kHz by a 16-bit D/A converter (DA8), attenuated (PA4), and passed through power amplifiers (Tascam) before presentation to the loudspeakers. Each loudspeaker had an LED affixed on its top surface, which was cont

A repeated measures ANOVA found significant main effects of condition [$F(2,18)=59.6$, $p<0.001$] and listener group [$F(1,9)=6.2$, $p<0.05$] and a significant interaction [$F(2,18)=7.9$, $p<0.005$]. Separate t-tests with Bonferroni corrections conducted on each cue type found both the WHERE and WHERE+WHEN cue benefits to differ significantly between the listener groups ($p<0.05$).

Fig 3: Mean percent correct scores (top panel) and mean cue benefits (bottom panel) for each group of listeners in the four attention conditions (error bars show standard errors).

DISCUSSION

As expected based on previous work, HI listeners were poorer overall at identifying a speech target embedded in a mixture of equal-level speech-like maskers. However, HI listeners did benefit from visual cues indicating where and when to listen for the target. While the magnitude of the temporal cue benefit was comparable between groups, the spatial cue benefit was smaller on average in the HI group, even when the groups were matched in terms of their baseline performance.

In the previous study (Best *et al.*, 2007), it was suggested that the spatial and temporal cues invoke different (and independent) modes of attention. This idea is supported by the current study, in that the WHERE and WHEN benefits were affected differentially by hearing loss, and were roughly additive. Temporal cues may have an “alerting” effect, which increases vigilance or arousal during the time epoch containing the target. This effect seems to have a relatively constant impact on performance, regardless of hearing status or overall

Shinn-Cunningham (these proceedings) suggests that reductions in spectral and temporal acuity in HI listeners impair the formation of auditory “objects,” which reduces the effectiveness of selective attention in choosing amongst competing objects. Extending this idea, it may be that reductions in spectral and temporal acuity also lead to degraded (or “blurred”) spatial representations and hence reduce the success with which spatially-directed attention can enhance one source selectively. We plan to test this idea directly in future experiments measuring spatial localization acuity in mixtures for NH and HI listeners.

In conclusion, the current results suggest that HI listeners do benefit from visual cues indicating where and when to listen when hearing out a target from a mixture. However, the benefit they receive from *spatial* information provided by visual cues is significantly worse than in NH listeners. An implication of this finding is that performance deficits shown by HI

Kidd, G. J., Arbogast, T. L, Mason, C. R., and Gallun, F. J. (**2005**). “The advantage of