Dichotic Word Recognition in Noise and the Right-Ear Advantage

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**Purpose:** This study sought to compare dichotic right-ear advantages (REAs) of young adults to older adult data (C. M. Roup, T. L. Wiley, & R. H. Wilson, 2006) after matching for overall levels of recognition performance. Specifically, speech-spectrum noise was introduced in order to reduce dichotic recognition performance of young adults to a level consistent with that of older adults with hearing loss.

**Method:** Dichotic word-recognition performance was evaluated in the free-recall response paradigm across 2 conditions: (a) quiet and (b) noise (+11 dB signal-to-noise ratio). Participants included a group of right-handed young adults ($n = 32$) with normal hearing.

**Results:** The introduction of noise resulted in significantly poorer dichotic word-recognition performance than in the quiet condition for the young adults. REAs, however, did not differ between the 2 conditions. Relative to the Roup et al. (2006) older adult data, performance of the young adults in the noise condition resulted in (a) similar levels of overall recognition performance and (b) significantly smaller REAs.

**Conclusions:** Results suggest that the magnitude of the REA is not dependent upon the difficulty of the dichotic task. Rather, the large REAs exhibited by older adults are more likely related to age-related deficits in auditory processing.

**KEY WORDS:** dichotic listening, right-ear advantage, aging

Dichotic speech recognition is a binaural auditory task that requires a listener to recall two different speech stimuli that are presented simultaneously to the two ears. For example, a word is presented to the right ear while a different word is simultaneously presented to the left ear. The listener is asked to recall one or both words, depending upon the response condition. It has long been recognized that most individuals exhibit better recognition performance for materials presented to the right ear (i.e., right-ear advantage [REA]; Kimura, 1967). The REA is thought to reflect the dominance of the left hemisphere in the perception of speech (Studdert-Kennedy & Shankweiler, 1970).

Dichotic listening has been used to measure age-related changes in auditory processing abilities in older adults (Bellis & Wilber, 2001; Golding, Carter, Mitchell, & Hood, 2004; Jerger, Alford, Lew, Rivera, & Chmiel, 1995; Noffsinger, Martinez, & Andrews, 1996; Roup, Wiley, & Wilson, 2006). Older adults exhibit reduced dichotic recognition performance relative to young adults across stimulus types (Jerger, Chmiel, Allen, & Wilson, 1994; Roup, Wiley, & Wilson, 2006; Strouse, Wilson, & Brush, 2000a, 2000b). Lower overall recognition performance is unsurprising given the difference in hearing sensitivity between these two groups. Older adults experience a high prevalence of peripheral sensorineural hearing loss (SNHL; Cruickshanks et al., 1998; Sindhusake et al., 2001) and, therefore, do poorer on most speech tasks.
In addition, across dichotic stimulus types, mean REAs of older adult listeners are consistently and significantly larger than REAs of young adult listeners (Jerger et al., 1994; Roup et al., 2006; Wilson & Jaffe, 1996). Larger REAs in older adults do not seem to be explained by differences in hearing sensitivity given symmetric hearing sensitivity between ears. Rather, inspection of the data across studies reveals that performance on materials presented to the left ear declines at a faster rate than on materials presented to the right ear, as a function of increasing age. The greater deficit in performance on materials presented to the left ear is the basis for the large REA observed in older adults and has been more appropriately described as a left-ear deficit (Jerger et al., 1994). Investigators speculate that the difference in REA magnitude between young and older adults reflects age-related changes in auditory processing beyond the level of the cochlea (Jerger et al., 1995). Specifically, it has been suggested that age-related declines in the interhemispheric transfer of information via the corpus callosum are, in part, responsible for the left-ear deficit exhibited by older adults (Bellis & Wilber, 2001; Jerger, 1997; Jerger et al., 1995). The observed left-ear deficit among older adults has been associated with poor speech-in-noise performance and, in some cases, rejection of binaural amplification (Allen, Schwab, Cranford, & Carpenter, 2000; Carter, Noe, & Wilson, 2001; Chmiel, Jerger, Murphy, Pirozzolo, & Tooley-Young, 1997).

The patterns of dichotic speech recognition performance observed among older adults with hearing loss, however, are based on comparisons with recognition performance of young adults with normal hearing. In particular, the differences in the magnitude of the REA between young and older adults are based on significant differences in overall levels of recognition performance. It could be that the typically small REA of young adults would increase significantly with a decrease in recognition performance similar to that exhibited by older adults. In this case, the larger REA exhibited by older adults may be a reflection of task difficulty rather than age-related declines in auditory processing. One way in which this assumption can be assessed is by reducing the dichotic recognition performance of young adults to a level consistent with that of older adults with hearing loss through the addition of background noise.

The impact of background noise on the REA has been previously investigated in young adult listeners (Cullen, Thompson, Hughes, Berlin, & Samson, 1974; Godfrey, 1974; Sequeira, Specht, Hämäläinen, & Hugdahl, 2008a, 2008b). Using white noise as a masker, Weiss and House (1973) reported a nonsignificant < 2% REA at a 0-dB signal-to-noise (S/N) ratio and a significant 6% REA at a −10-dB S/N ratio for CVC words. Cullen et al. (1974), on the other hand, measured dichotic CV recognition in band-limited masking noise. Cullen et al. observed that the mean REA in their group of young adult listeners remained essentially unchanged across multiple S/N ratios (~5% REA). More recently, Sequeira and colleagues (2008a, 2008b) measured dichotic CV recognition in mult talker babble and traffic noise and reported a significant decrease in the REA relative to a quiet condition in their group of young adult listeners. The differences in methodology between studies—particularly, the type of background noise used—likely explain the differential effects of noise on the REA. When comparing the REAs of young adults with normal hearing to those of older adults with SNHL, however, no study has reported an increase in the REA due to noise of the same magnitude as that observed in older adult listeners. In a group of young adult listeners, Godfrey (1974) reported an overall REA of 6% across S/N ratios for dichotic CV recognition in white noise. Noffsinger et al. (1996), however, reported an REA of 16.8% for a group of older adults on a similar dichotic CV task. This suggests that although the REA for young adults with normal hearing may increase with the introduction of background noise, the magnitude appears to remain smaller than that exhibited by older adults.

The purpose of the present study was to determine if differences in the dichotic REA exist between young adults with normal hearing and previously published data from a group of older adults with SNHL (Roup et al., 2006) after matching for overall dichotic word-recognition performance. Specifically, dichotic word-recognition performance in a background of speech-spectrum noise was measured in a group of young adults with normal hearing and then compared to performance reported for older adults on the same task. If the assumption that large REAs are due to age-related changes in auditory processing is correct, then the REAs of young adults under the noise condition should remain small. If, on the other hand, the large REAs exhibited by older adults are due to task difficulty, then the REAs of young adults under the noise condition should be significantly larger than under the quiet condition.

### Method

**Subjects**

Thirty-two right-handed young adults (17 female, 15 male) participated in the present study. The subjects ranged in age from 18 to 30 years with a mean age of 22.6 years. All subjects had normal hearing sensitivity, defined as pure-tone thresholds ≤ 20 dB HL for 250–8000 Hz. Bone-conduction thresholds were within 10 dB of air-conduction thresholds for 500–4000 Hz. Inclusion criteria included (a) normal otoscopy, (b) negative history of recent otic pathology, (c) screening tympanometry within normal limits (Roup, Wiley, Safady, & Stoppenbach,
Dichotic word recognition was measured using the Northwestern University Auditory Test No. 6 (NU–6; Tillman & Carhart, 1966) monosyllabic words from the Department of Veterans Affairs Speech Recognition and Identification Materials, Disc 1.1 (Department of Veterans Affairs, 1991). The 200 NU–6 monosyllabic words were paired to create 100 dichotic word pairs that included the carrier phrase “say the word” presented diotically. For details regarding the compilation of the dichotic word pairs, see Roup et al. (2006). In order to create a list of dichotic words in noise, each two-channel word pair was mixed with antiphase speech-spectrum noise (American National Standards Institute [ANSI], 2004) at an S/N ratio of +11 dB using speech editing software (Adobe Audition Version 1.5). Pilot data gathered prior to the experiment confirmed that dichotic word-recognition performance did not differ according to noise type (e.g., homophasic, antiphasic, or uncorrelated). Therefore, antiphasic speech-spectrum noise was selected in order to maintain lateral rather than midline perception. Pilot data also suggested that an S/N ratio of +11 dB would produce recognition performance levels in the 40%–60% range. This range of recognition performance was chosen to be consistent with dichotic word-recognition performance levels exhibited by older adults for the same dichotic NU–6 word list (i.e., Roup et al., 2006). Multiple randomizations of the word lists were generated for both quiet and noise conditions and were recorded on a CD. Each randomization was recorded as four lists of 25 word pairs. A 4.5-s interstimulus interval was used.

**Results**

**Condition Comparisons**

Mean dichotic word recognition and SDs for the quiet and noise conditions are presented in Table 1. Mean data for a group of older adults from Roup et al. (2006) are included for comparison. As can be seen in Table 1, dichotic word-recognition performance was reduced by the introduction of noise relative to the quiet condition for the young adult listeners. Specifically, mean recognition performance decreased by 33.3% and 34.3% for the right and left ears, respectively. In order to determine if the decrease in performance due to noise was significant, the percentage data were transformed to rationalized arcsine units (Studebaker, 1985) and were subjected to a two-way repeated-measures analysis of variance (ANOVA), with condition and ear as within-subjects factors. The ANOVA revealed a significant main effect for condition, $F(1, 31) = 333.3, p < .05$, indicating that dichotic word-recognition performance was significantly worse in noise than in quiet. The ANOVA also revealed a significant main effect for ear, $F(1, 31) = 12.9, p < .05$, indicating that performance on words presented to the right ear was significantly worse than that of the left ear.

<table>
<thead>
<tr>
<th>Group</th>
<th>Right ear (%)</th>
<th>Left ear (%)</th>
<th>RE – LE (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Young adults</td>
<td>84.8</td>
<td>7.7</td>
<td>80.1</td>
</tr>
<tr>
<td>Noise</td>
<td>51.5</td>
<td>13.1</td>
<td>45.8</td>
</tr>
<tr>
<td>Older adults</td>
<td>56.8</td>
<td>19.3</td>
<td>43.0</td>
</tr>
</tbody>
</table>

Note. The older adult data from Roup et al. (2006) are included for comparison. The older adult data have been combined into one group from two age groups (60–69 years and 70–77 years) in the original article.
better than performance on words presented to the left ear.

Mean REAs across conditions are also presented in Table 1. The magnitude of the mean REA also changed with the introduction of noise. Specifically, the mean REA increased from 3.3% in the quiet condition to 5.9% in the noise condition. A t test of means was used to compare mean REAs between experimental conditions. Results did not reveal a significant difference in mean REAs between the quiet and noise conditions, t(31) = −0.1, p > .05. Although the introduction of noise significantly reduced overall dichotic word-recognition performance, a corresponding significant change in the magnitude of the REA was not observed.

**Age Comparisons**

The purpose of adding noise to the dichotic word-recognition task was to reduce overall performance of the young-adult subjects to levels consistent with performance exhibited by older adults on the same task. For purposes of comparison, the two groups of older adult data (ranges = 60–69 and 70–77 years) from Roup et al. (2006) were combined into one group (n = 36, range = 60–77 years). Figure 1 presents individual data as a bivariate plot for the young adults (quiet and noise conditions) and the Roup et al. older adults, with the percent correct recognition for the words presented to the right ear on the abscissa and the percent correct recognition for the words presented to the left ear on the ordinate. The data points below the diagonal line indicate better performance on the words presented to the right ear (i.e., an REA), and those above the line indicate better performance on the words presented to the left ear (i.e., a left-ear advantage). The data points on the diagonal line indicate equal performance for words presented to each ear. As can be seen in Figure 1, recognition performance of the young adults from the noise condition (filled triangles) was quite similar to that of the Roup et al. older adult data (open squares), although the older adult data demonstrate greater variability. In order to determine if significant differences in performance existed between the young adults in noise and the Roup et al. older adults, we transformed the percentage data to rationalized arcsine units (Studebaker, 1985) and conducted a one-way ANOVA, with group as the between-subjects factor. Results did not reveal a significant difference in overall (i.e., both ears) dichotic word-recognition performance between the young adults in noise and the Roup et al. older adults, F(1, 66) = 0.01, p > .05. In other words, recognition performance was successfully matched between young adults with normal hearing and older adults with SNHL by the introduction of noise.

The data in Table 1 illustrate the difference in the magnitude of the mean REA observed between young and older adults. Specifically, the mean REA exhibited by the Roup et al. older adults (13.8%) was significantly larger than that of the young adults in both the quiet condition (3.3%), t(67) = −1.8, p < .05, and the noise condition (5.9%), t(67) = −1.7, p < .05. Large ear advantages exhibited by older adults are particularly evident when considering the five data points in the bottom right of Figure 1. These five data points represent older adult individuals with few if any responses from the left ear, illustrating a substantial deficit in the process of dichotic stimuli.

**Discussion**

The implication that the left-ear deficits exhibited by older adults on dichotic speech recognition tasks are due to age-related deficits in auditory processing abilities is based primarily on the comparison of ear advantages between two groups with very different levels of overall recognition performance: young adults with normal hearing sensitivity and older adults with SNHL. The purpose of the present study, therefore, was to reduce dichotic word-recognition performance through the introduction of noise in a group of young-adult listeners, matching their performance to older adult data on the same dichotic task. Results revealed significantly poorer
overall dichotic word-recognition performance due to the introduction of noise relative to the quiet condition. When recognition performance of the young adults in the noise condition was compared to the Roup et al. (2006) older adult data, no significant differences were found. The introduction of noise, therefore, successfully matched recognition performance of the young adults to that of older adults on the same dichotic word-recognition task.

In addition, results from the present study suggest that the REAs of young adults do not change significantly, despite significant reductions in overall recognition performance. The difference in REAs between the young and older adults, therefore, remains intact. Similar levels of dichotic word-recognition performance to that of the present study were reported by Dirks (1964) for low-pass filtered words in a group of young adults (40.3% and 33.3% for the right and left ears, respectively). The mean REA for the Dirks group was 7.0%, comparable with the mean REA exhibited by the young adults in the noise condition (5.9%) from the present study, yet approximately half of the mean REA exhibited by the Roup et al. (2006) older adults (13.8%). Although there is some degree of overlap between groups (see Figure 1), the spread of individual data demonstrates the greater variability and larger ear advantages associated with older adult dichotic word-recognition performance.

Conclusions and Clinical Implications

Background noise has often been used to reduce speech-recognition performance of young adults in an effort to make their results more comparable to those of older adults with hearing loss. It should be noted, however, that it is not possible to perfectly emulate the effects of age-related SNHL experienced by older adults through the addition of background noise. The results from the present study are, therefore, somewhat limited, based on the fact that direct comparisons between young adults with normal hearing and older adults with age-related SNHL cannot be made. The introduction of noise to the dichotic word-recognition task served simply to provide similar levels of recognition performance from which more direct comparisons of ear advantages could be made.

Given that the REAs of the young adults did not increase significantly with the introduction of noise, the results of the present study suggest that the large REAs, or left-ear deficits, exhibited by older adults are not related to the difficulty of the dichotic task but, rather, are related to deficits in the processing of binaural competing signals. Deficits in binaural auditory processing among older adult listeners have been associated with a lack of benefit from binaural amplification (Allen et al., 2000; Carter et al., 2001; Jerger et al., 1994). The ability to identify those older adults with binaural auditory processing deficits prior to hearing-aid fitting may allow for improved fitting and counseling strategies, which in turn may result in improved perceived benefit from amplification. Further research is needed to identify specific patterns of recognition performance on dichotic speech-recognition tasks that would indicate potential binaural processing deficits related to rejection of binaural amplification.

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References


