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Dichotic Word Recognition in Young and Older Adults

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Abstract

Dichotic word recognition was evaluated in free-recall, directed-attention right, and directed-attention left response conditions. All participants were right-handed and included a group of young adults with normal hearing and two groups of older adults with sensorineural hearing loss. Dichotic word recognition performance was best for young adults and decreased for each older group. A right-ear advantage (REA) was observed for all groups. REAs observed in the older groups were larger than those for the young adults, resulting from a greater deficit in dichotic word recognition performance for words presented to the left ear. A subset of older adults exhibited few to no responses (≤3/100) for the left ear for all response conditions, which may relate to a compromise in auditory processing. The results support an age-related disadvantage in recognition performance for dichotic stimuli presented to the left ear not entirely accounted for by differences in hearing sensitivity between subject groups.

Key Words: Aging, dichotic listening tests, hearing impaired, speech perception

Abbreviations: HSD = honestly significant difference; LEA = left-ear advantage; REA = right-ear advantage; VA = Veterans Affairs

Sumario

Se evaluó el reconocimiento de palabras dicóticas en condiciones de respuesta de evocación libre, de atención dirigida a la derecha y de atención dirigida a la izquierda. Todos los participantes eran diestros y se incluyó un grupo de adultos jóvenes con audición normal y dos grupos adultos más viejos con hipoacusia sensorineural. El desempeño en el reconocimiento de palabras dicóticas fue mejor para los adultos jóvenes, y disminuyó para los otros dos grupos. Se observó una ventaja para el oído derecho (REA) en todos los grupos. La REA observada en los grupos de mayor edad fue mayor que aquella de los adultos jóvenes, como resultado de un mayor déficit en el reconocimiento de palabras dicóticas presentadas al oído izquierdo. Un subgrupo de adultos mayores mostró pocas respuestas o ausencia de ellas (≤3/100) en el oído izquierdo, en todas las condiciones de respuesta, lo que puede relacionarse con un problema en el procesamiento auditivo. Los resultados apoyan una desventaja relacionada con la edad en el reconocimiento de estímulos dicóticos presentados al oído izquierdo, no totalmente explicada por las diferencias de sensibilidad auditiva ente los grupos de sujetos.

Palabras Clave: Envejecimiento, pruebas dicóticas de audición, hipoacúsico, percepción del lenguaje

Abreviaturas: HSD = diferencia honestamente significativa; LEA = ventaja del oído izquierdo; REA = ventaja del oído derecho; VA = Asuntos de Veteranos

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Dichotic listening refers to the condition in which one auditory stimulus is presented to the right ear and a second, different stimulus is presented simultaneously to the left ear. The difficulty of the dichotic listening task is dependent upon the type of stimuli presented to the two ears. At one end of the dichotic difficulty continuum, broadband noise in one ear does little to disrupt the intelligibility of speech in the other ear. At the other end of the continuum, a speech signal in one ear can be quite disruptive to the intelligibility of speech in the other ear. The most dramatic effect is when speech signals of similar characteristics (e.g., words or nonsense syllables) are presented to the ears simultaneously. Recognition performance on dichotic speech tasks is typically better on materials presented to the right ear than on materials presented to the left ear, which is referred to as a right-ear advantage (REA) (Kimura, 1961). The REA varies with the handedness of the listener. The REA exhibited by left-handed listeners is typically smaller and more variable than that of right-handed listeners (Wilson and Leigh, 1996).

Dichotic speech recognition is typically measured under two types of response formats: free recall and directed-attention recall. In the free-recall condition, listeners are instructed to recall both dichotic stimuli regardless of order. Free recall consistently results in an REA in most young and older adult listeners. In contrast, the directed-attention response format implies that attention, or cueing, is provided to the listener prior to stimulus presentation. Specifically, listeners are instructed, or cued, to attend to a specific ear prior to stimulus presentation. Directed-attention recognition performance has been evaluated under different response paradigms. The most common and simplest directed-attention response paradigm requires the listener to attend and recall the stimulus from the cued ear while ignoring the stimulus presented to the noncued ear. For example, under directed-attention right, the listener is instructed to recall the stimulus presented to the right ear while ignoring the stimulus presented to the left ear. A second, more difficult directed-attention response paradigm requires the listener to recall the dichotic stimuli presented to both ears *with* regard to order. In this case, the listener is instructed to recall the stimulus presented to the cued ear first followed by the stimulus presented to the noncued ear. For example, under directed-attention left, the listener is instructed to recall the stimulus presented to the left ear first and then recall the stimulus presented to the right ear. Previous investigations confirm that both types of directed-attention response paradigms result in ear advantages in the direction of cueing (Wilson et al, 1968; Asbjørnsen and Hugdahl, 1995; Asbjørnsen and Bryden, 1996; Strouse et al, 2000a, 2000b). Therefore, regardless of the response paradigm, directed attention affects the magnitude and direction of ear advantage. In most cases, directed attention to the right-ear results in an REA, whereas directed attention to the left shifts the direction of the ear advantage to the left ear (i.e., left-ear advantage [LEA]). The magnitude of the ear advantage is also larger under the directed-attention response format than it is under free recall.

Dichotic speech recognition has been used to assess auditory processing in older adults (Stach et al, 1990; Jerger et al, 1995; Noffsinger et al, 1996; Wilson and Jaffe, 1996; Strouse and Wilson, 1999a, 1999b; Strouse, et al, 2000a, 2000b; Bellis and Wilber, 2001). In general, the effects of aging on dichotic speech recognition result in poorer performance and larger REAs for older adults relative to findings for young adults. Differences in performance between young and older adults is not surprising given that older adults exhibit a greater prevalence of hearing loss with increasing age (Cruickshanks et al, 1998; Adams et al, 1999). Larger REAs in older adults, however, cannot be explained fully by differences in hearing sensitivity. Inspection of individual ear data reveals that the larger REAs exhibited by older adults can be attributed to a greater deficit in performance on materials presented to the left ear relative to that of the right ear. The deficit in performance on materials presented to the left ear is exaggerated relative to that for young adults and has been described as a left-ear disadvantage (Jerger et al, 1994). Further, with increases in age, dichotic-recognition performance on materials presented to the left ear declines at a disproportionate rate compared to that of the right ear (Jerger et al, 1994; Noffsinger, et al, 1996; Wilson and Jaffe, 1996; Strouse and Wilson, 1999b; Bellis and Wilber, 2001). Jerger et al (1995) suggested that age-related changes in auditory processing are due, in part, to a decline in the efficiency of interhemispheric transfer of auditory information via the corpus callosum. This is fundamental to the left-ear disadvantage exhibited by older adults and the associated difficulties understanding speech in the presence of a competing message.

Of the variety of speech stimuli available to measure dichotic speech recognition (e.g., digits, words, consonant-vowels and sentences), digits are the most utilized. An advantage of digit stimuli is that, unlike sentences, they limit contextual cues. Digits, however, are a closed-set task that may tend to overestimate dichotic speech recognition ability. Digits are highly familiar, are quite limited in the available number of possible responses, and have been shown to be relatively easy to recognize for both normal hearing and hearing-impaired listeners (Musiek, 1983; Speaks et al, 1985; Strouse and Wilson, 1999a, 1999b). As an alternative, monosyllabic words (other than digits) may offer several advantages as a dichotic stimulus including: (1) monosyllabic words are meaningful components of speech that limit the use of syntactical cues (Committee for Hearing, Bioacoustics and Biomechanics [CHABA], Working Group on Speech Understanding and Aging, 1988); (2) recorded monosyllabic word lists offer a standardized test of word recognition that are commercially available and in widespread use; (3) there is a large normative database for these monaural word-recognition materials from listeners with normal hearing and listeners with hearing loss across age groups in both quiet and competing message listening environments (Dubno et al, 1995; Dubno et al, 1997; Sperry et al, 1997; Wiley et al, 1998; Stoppenbach et al, 1999; Stockley and Green, 2000); and (4) unlike digits, words are an open stimulus set that may result in recognition performance in the middle of the difficulty continuum (e.g., neither too easy nor too difficult, yet sensitive to performance differences between ears and groups). Currently, available data documenting dichotic monosyllabic-word recognition performance—other than dichotic digits—is limited for both young and older adults (Dirks, 1964; Prior et al, 1984).

The purpose of the present study was to determine if differences in dichotic word recognition performance exist between young adults with normal hearing and two age groups of older adults with sensorineural hearing loss. The present study also sought to determine if the same groups of listeners exhibit a difference in recognition performance between ears for dichotic word stimuli (i.e., an REA). A further purpose was to determine if attention, or cueing, results in performance differences (free recall versus directed-attention right and left) among young and older adult listeners.

METHODS

Subjects

Fifty-four right-handed male listeners participated. The subjects were grouped into the following three age groups: Group I consisted of 18 young males 19–30 years of age (mean age = 25.6 years) with normal hearing (≤20 dB HL at 250–8000 Hz); Group II consisted of 18 older males with sensorineural hearing loss aged 60–69 years (mean age = 64.3 years); and Group III consisted of 18 older males with sensorineural hearing loss aged 70–79 years (mean age = 73.8 years). The young adult subjects were recruited from the student population at the East Tennessee State University and the surrounding community. The older adult subjects were recruited from the ongoing audiology clinics at the James H. Quillen Veterans Affairs (VA) Medical Center. The mean hearing thresholds (and standard deviations) at 250–8000 Hz for all subjects are listed in Table 1. In order to minimize the variability associated with differing degrees of peripheral hearing loss, participation in Groups II and III was limited to individuals meeting a preset 10 dB threshold range at 500–4000 Hz. The pre-set threshold range was based on the mean threshold data of the 70–79 year age group from the Cruickshanks et al (1998) Epidemiology of Hearing Loss Study. The following ranges (dB HL) were used: 10–20 (500 Hz), 15–25 (1000 Hz), 25–35 (2000 Hz), 45–55 (3000 Hz), and 55–65 (4000 Hz). Comparisons of mean thresholds between Groups II and III (paired t-tests) did not reveal any significant differences between group thresholds for 500–4000 Hz ($p > .05$). In order to avoid asymmetric hearing loss, air-conduction thresholds between ears were within ±5 dB at 500–4000 Hz. Air-

Table 1. Mean Hearing Thresholds (dB HL) and Standard Deviations (SD) for Groups I, II, and III, Combined across Right and Left Ears

	Frequency (Hz)						
	250	500	1000	2000	3000	4000	8000
Group I (19–30 years)							
Mean	9.2	7.8	6.3	3.5	–	9.2	5.6
SD	6.9	5.5	4.5	5.5	–	7.2	6.2
Group II (60–69 years)							
Mean	18.2	15.6	19.2	29.4	51.1	60.3	60.4
SD	8.5	4.4	5.3	4.4	4.3	4.6	14.1
Group III (70–79 years)							
Mean	20.0	15.0	18.9	29.6	51.1	61.5	65.8
SD	5.5	4.5	4.2	4.5	4.5	4.1	10.2

conduction thresholds did not differ by more than 10 dB from bone-conduction thresholds at 500–4000 Hz for all subjects.

All subjects had monaural word-recognition scores of 80% or better for the Northwestern University Auditory Test No. 6 (NU-6) monosyllabic words (50-word list) for right and left ears under headphones in quiet. The NU-6 words were presented at 50 dB HL for Group I and at 80 dB HL for Groups II and III using the VA recorded version with a female speaker (Speech Recognition and Identification Materials 2.0, Department of Veterans Affairs, 1998). Each subject had normal otoscopic findings and no history of otic disease or disorder within the last year. Tympanometry measures were within normal limits (Wiley et al, 1996; Roup et al, 1998). Due to the variability in dichotic speech recognition performance associated with left-handed listeners (Wilson and Leigh, 1996), all subjects in the present study were right-handed. Handedness was determined by a 10-item questionnaire (Oldfield, 1971). Normal cognitive status was determined with the Mini-Mental State Examination (score ≥25) (Folstein et al, 1975).

Materials

The 200 NU-6 monosyllabic words spoken by a female speaker from the Department of Veterans Affairs compact disc (CD) Speech Recognition and Identification Materials 1.1 (VA Medical Center, Long Beach, CA, 1991) were used to create the 100 dichotic word pairs used in this study. The NU-6 recordings included the carrier phrase "say the word" followed by the monosyllabic word. First the words were parsed into single-channel, individual files from which the duration of each carrier phrase was determined (Cool Edit Pro™, 1997). The words then were rank ordered according to the durations of the carrier phrases. In this manner the onsets of the carrier phrases and words that were adjacent in the rank ordering essentially were simultaneous. In addition to word pairings that were based on the carrier-phrase duration, word pairs with the same phonemes in the same word positions were avoided, and each of the 200 words was used only once. Individual two-channel files were created for each word pair. These files were concatenated to form seven randomizations of the 100-word pairs that were recorded on CD. Each randomization was recorded as four lists of 25-word pairs. A 4.5 second interstimulus interval was used.

Procedures

Dichotic word recognition was measured under three response conditions: (1) free recall, (2) directed-attention right, and (3) directed-attention left. In the free-recall condition, the listeners were instructed to repeat both words, after the carrier phrase, without regard to order. In the directed-attention conditions, the listeners were instructed to repeat the word presented to the directed or cued ear first followed by the word presented to the opposite or noncued ear. The free-recall condition was presented first to all subjects followed by the directed-attention conditions. The order of presentation of directed-attention conditions (right and left) was alternated between listeners. Each condition consisted of 100 dichotic word trials made up of four randomizations of 25 word pairs. The randomizations were counterbalanced among the subjects in order to control for order effects. The dichotic words were presented from a CD player (Sharp DX-R250) through a two-channel audiometer (Grason Stadler, Model 16) at 50 dB HL for Group I and at 80 dB HL for Groups II and III. The channel through which the dichotic words were presented to the right and left ears was alternated between response conditions. A short familiarization procedure consisting of four 25-word lists from a different randomization than those used in the experiment was used to acquaint the subjects with the dichotic task. The subjects heard up to 30 practice samples of the dichotic word stimuli, including ten each for free recall, directed-attention right, and directed-attention left prior to data collection. The subjects responded verbally, and the responses were recorded on a score sheet as correct or incorrect. Each subject participated in a single one-hour session. All audiometric and experimental testing was conducted in a double-wall sound booth (IAC, Model 1205) under headphones (Telephonics TDH-50). Both the audiometer and tympanometer were calibrated according to the appropriate American National Standards Institute standards (ANSI, 1987, 2004).

RESULTS

The individual data for the three subject groups by response condition are presented as bivariate plots in Figure 1 with the percent correct recognition for the words presented to the right ear on the abscissa and percent correct recognition for the words presented to the left ear on the ordinate. The filled symbols denote the mean data for each subject group. The data points below the diagonal line indicate better performance on the words presented to the right ear (i.e., a right-ear advantage), and those above the diagonal 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. Because of superimposed data points, the numbers in parentheses are included in the figure to indicate the exact distribution of the data. For example, in the free-recall condition, 11 of the young subjects (squares) had REAs, 6 had LEAs, and 1 had equal performances. As can be seen in Figure 1, recognition performance

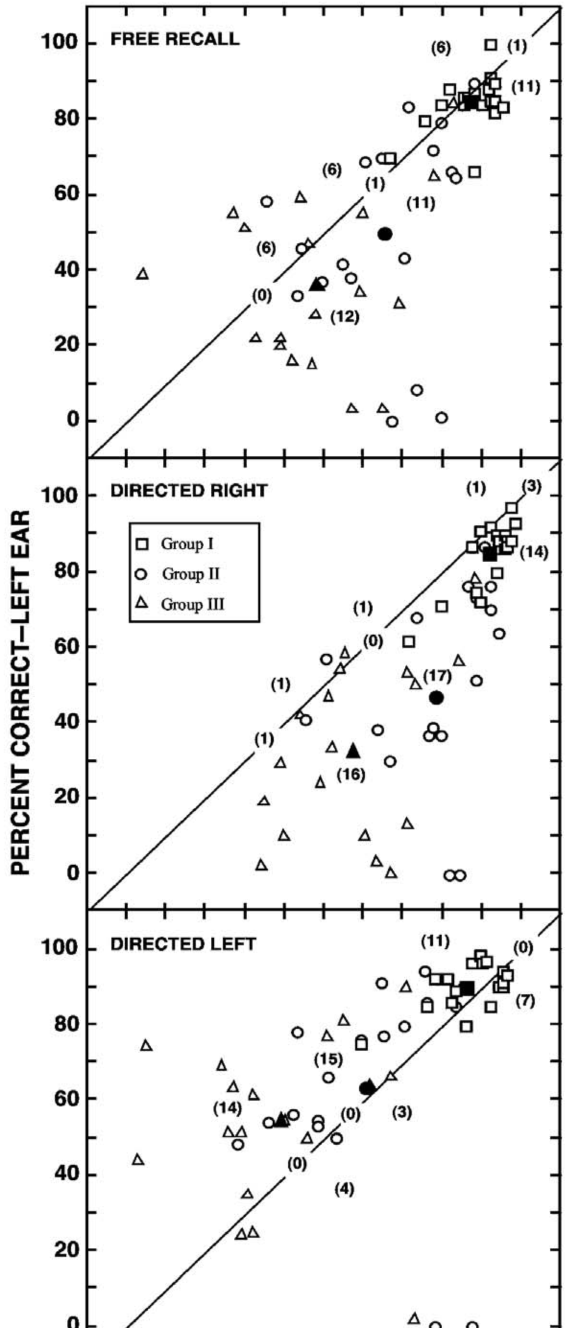

Figure 1. Bivariate plot of percent correct recognition for the right ear (abscissa) and percent correct recognition for the left ear (ordinate) across the three response conditions. The filled symbols in each panel denote the mean data. The numbers in parenthesis indicate the exact distribution of data for each subject group: equal performance on the line, better right ear performance below the line, and better left ear performance above the line.

for the young group (squares) was better and more homogeneous than recognition performance for either older group (circles and triangles) in each response condition. Further, performance for the 60–69 year group (circles) was better than performance for the 70–79 year group (triangles) in all response conditions.

The numbers in parentheses in Figure 1 illustrate the effect of cueing in the different response conditions. Specifically, the distribution of the data follows a specific pattern depending on the response condition. For all subject groups, the majority of individual data points (47 for the three groups of listeners) fall below the line (REA) for directed-attention right or above the line (LEA) for directed-attention left (40), whereas there was a more homogeneous spread of data points around the line of equal performance for free recall. These findings also are evident when examining the mean data listed in Table 2. All subject groups exhibited mean REAs in the free-recall and directed-attention right conditions, and mean LEAs in the directed-attention left condition. The size of the REA for directed-attention right was approximately double that of the REA for free recall for all subject groups. The LEAs exhibited by all subject groups for directed-attention left were smaller and more variable than the REAs observed for directed-attention right.

Prior to further statistical analysis, the dichotic word recognition percentage data were transformed to a rationalized arcsine that was conducted to normalize the error variance associated with percentage data (Studebaker, 1985). The transformed data were examined using a mixed model analysis of variance (ANOVA) with *age* as the between-subjects factor, and *response condition* and *ear* as within-subjects factors. A significance level of 0.05 was used for all statistical tests of means. The ANOVA revealed a significant main effect for *age* ($F_{2,51} = 41.44$, $p < .05$). Post hoc analysis on the effect of *age* using Tukey's honestly significant difference (HSD) test revealed significant differences ($p < .05$) in recognition performance between the young group and both older groups. There was not, however, a significant difference in

Table 2. Mean Dichotic Word-Recognition Performance (in percent correct) and Standard Deviations (SD) for Groups I, II, and III for Free-Recall, Directed-Attention Right, and Directed-Attention Left Response Conditions

		Right Ear (%)	Left Ear (%)	RE – LE (%)
Free-Recall				
Group I	Mean	86.9	84.4	2.5
(19–30 years)	SD	7.6	7.4	7.6
Group II	Mean	65.2	49.9	15.3
(60–69 years)	SD	15.6	27.3	28.1
Group III	Mean	48.3	36.1	12.3
(70–79 years)	SD	19.3	22.4	26.4
Directed-Attention Right				
Group I	Mean	91.3	84.6	6.7
(19–30 years)	SD	6.9	9.1	5.1
Group II	Mean	78.1	46.9	31.2
(60–69 years)	SD	14.1	27.3	27.4
Group III	Mean	57.2	32.3	24.9
(70–79 years)	SD	16.1	23.4	21.4
Directed-Attention Left				
Group I	Mean	86.4	89.9	-3.6
(19–30 years)	SD	9.2	6.0	7.2
Group II	Mean	60.6	63.3	-2.6
(60–69 years)	SD	17.9	27.7	32.3
Group III	Mean	39.0	54.4	-15.4
(70–79 years)	SD	20.7	22.3	29.2

performance between the two older groups. Significant main effects also were present for the within-subject factors of *response condition* ($F_{2, 102} = 18.54$, $p < .05$) and *ear* ($F_{1, 51} = 9.15$, $p < .05$). Tukey's HSD post hoc analysis on the effect of *response condition* did not reveal significant differences in performance for the young group. Significant differences in *response condition* ($p < .05$) were present for the older groups of subjects. Specifically, the 60- to 69-year-old group performed significantly better in the directed-attention right condition compared to the free-recall condition; and both of the older groups performed significantly better on the directed-attention left condition than on the free-recall condition. Post hoc analysis on the main effect for *ear* revealed significantly better recognition performance on words presented to the right ear than on words presented to the left ear for both older groups. The difference in performance for the right and left ears in the young group was not significant.

Significant interactions also were present for *response condition* x *ear* ($F_{2, 102} = 43.02$, $p < .05$) and *age* x *response condition* x *ear* ($F_{4, 102} = 3.49$, $p < .05$). The interaction of *response condition* x *ear* was due to better recognition performance of the left ear for the directed-attention left condition versus better recognition performance of the right ear for both the free-recall and directed-attention right conditions (see Figure 1). The significant interaction of *age* x *response condition* x *ear* reflects the fact that performance on dichotic words presented to the right and left ears varied as a function of both *age* and *response condition*. Specifically, the performance difference between ears (i.e., REA) was larger for the two older groups than for the young group, and the REAs observed in the directed-attention right condition were larger than the ear advantages (right or left) observed in the free-recall and directed-attention left conditions for all subject groups. For example, the 60–69 year group exhibited a 31.2% REA for the directed-attention right condition compared to a 15.3% REA for free recall and a 2.6% LEA for directed-attention left response conditions. Although the REA for the directed-attention right condition was larger than the ear advantages for the other two conditions, all mean ear advantages for the young group were smaller than those for both older groups.

DISCUSSION

Age Comparisons

The primary purpose of the present study was to determine if differences in dichotic word-recognition performance exist between young adults with normal hearing and two age groups of older adults with sensorineural hearing loss. Comparisons of recognition performance collapsed across ears, and response condition revealed significantly better performance for the young adults with normal hearing relative to that for both older groups with sensorineural hearing loss. Poorer recognition performance for older listeners compared to young listeners is well documented for dichotic speech recognition measures (Jerger et al, 1994; Wilson and Jaffe, 1996; Strouse et al, 2000a) and may be, in part, attributable to differences in hearing sensitivity. Differences in recognition performance collapsed across ears and response condition between the 60–69 and 70–79 year groups were not statistically significant.

The most consistent finding from the dichotic speech recognition literature is the presence of an REA across right-handed subject populations. The present study was no exception; all subject groups exhibited mean REAs for the free-recall response condition. The observed REAs in the young group were small and approached maximum performance. In contrast, the 60–69 and 70–79 year groups exhibited significant differences in recognition performance on words presented to the right and left ears, resulting in mean REAs of 15.3% and 12.3%, respectively. The size of REAs observed in the older groups is consistent with previous reports of dichotic speech recognition for older listeners that reported REAs ranging from 10–20% (Jerger et al, 1994; Noffsinger et al, 1996; Wilson and Jaffe, 1996; Strouse and Wilson, 1999a; Strouse et al, 2000a). A comparison of REAs (paired *t*-test) revealed that the REAs exhibited by the older groups were significantly larger ($p < .05$) than the mean REA exhibited by the young adult group. Based on comparisons of mean REAs between young and older listeners from the present study and previous investigations, REAs exhibited by older listeners are exaggerated relative to those for young listeners.

Although the presence of sensorineural

hearing loss among the older groups is the most likely factor contributing to differences in overall dichotic word-recognition performance between the young and older groups, differences in hearing sensitivity do not seem to explain the larger REAs exhibited by the older groups. An accumulation of evidence, including that from the present study, suggests that the larger REAs exhibited by older listeners are primarily due to a greater deficit in performance on dichotic stimuli presented to the left ear (i.e., a left-ear disadvantage) (Jerger et al, 1994; Noffsinger et al, 1996; Wilson and Jaffe, 1996; Divenyi and Haupt, 1997; Strouse and Wilson, 1999a, 1999b; Bellis and Wilber, 2001). The left-ear disadvantage exhibited by the older groups in the present study and in previous reports suggests that some dysfunction in auditory processing is evident during dichotic stimulation. Support for this premise lies in the fact that the older subject groups from the present study that exhibited a left-ear disadvantage also exhibited normal monaural word-recognition performance in quiet (≥80%) for the same NU-6 words for both right and left ears.

An advantage of using the NU-6 words as the dichotic speech stimulus for the present study was that it allowed for the direct comparison of monaural and dichotic word-recognition scores for the same speech stimuli spoken by the same speaker in the same pool of subjects. Comparisons of monaural and dichotic (e.g., free-recall) word-recognition scores within the same ear (paired *t*-tests) revealed significantly better scores ($p < .05$) for monaural presentation than for dichotic presentation in both right and left ears for all subject groups. Both the young and older adult subjects were able to recognize the NU-6 words with ease (≥80%) when presented monaurally in quiet conditions; however, binaural dichotic presentation of the same stimuli resulted in significantly poorer recognition performance. For the young group, the difference between monaural and dichotic recognition performance was 12% and 14% for the right and left ears, respectively. Similar results were reported by Dirks (1964) in a group of young adults with normal hearing. Dirks found a significant REA for filtered dichotic words; however, monaural recognition of the same filtered words was nearly identical between ears. The difference between monaural and dichotic recognition performance was more pronounced for the older adult groups from the present study. The 60–69 year group had a monaural to dichotic difference of 23% and 42% for the right and left ears, respectively, whereas the 70–79 year group had a difference of 39% and 54% for the right and left ears, respectively. The results of this monaural versus dichotic comparison indicate that a deficit in auditory processing may only be evident during degraded speech tasks like binaural competing conditions (e.g., dichotic listening) or within a competing message listening environment—also reflecting the lack of sensitivity of speech recognition measures in quiet.

The left-ear disadvantage exhibited by older adults for dichotic stimuli is thought to reflect age-related changes in auditory processing, particularly a decline in the efficiency of interhemispheric transfer of information via the corpus callosum (Jerger et al, 1995). Because dichotic stimuli presented to the left ear are first routed to the right hemisphere through the dominant contralateral auditory pathway, the stimuli then have to cross interhemispheric pathways (i.e., the corpus callosum) to be processed in the left hemisphere. Degenerative changes of the corpus callosum due to aging (Janowsky et al, 1996; Jeeves and Moes, 1996; Greenwald and Jerger, 2001) may result in a loss of neural information when competing signals are present, and therefore, fewer stimuli presented to the left ear would ultimately be available for recognition by the left hemisphere. There appears to be an age-related deficit in the auditory processing that is necessary to separate the speech stimulus of interest from a competing message (Warren et al, 1978; Divenyi and Haupt, 1997). Divenyi and Haupt (1997), for instance, reported the results of a variety of binaural speech recognition measures in a competing message for a group of older listeners (60–81 years). The older listeners consistently exhibited poorer recognition performance for materials presented to the left ear relative to performance in the right ear for all speech measures made in the presence of a competing message, including a dichotic word task. The above results offer support for a link between the processing of speech in a competing message and the processing of dichotic speech signals.

Directed-Attention Comparisons

A second purpose of the present study was to determine the effect of directed attention on dichotic word-recognition performance. In the case of the present study, subjects were instructed to recall both words during the directed-attention conditions, with the cued ear to be recalled first. This type of directed-attention response format was chosen in order to obtain ear difference scores (i.e., ear advantages) in the same manner as the free-recall response condition. Directed attention had little effect on the overall recognition performance in the young group; differences in performance between response conditions were not significantly different. In contrast, both older adult groups exhibited superior performance on the directed-attention conditions as compared to the free-recall condition. With the older groups, the effect of attention resulted in better overall performance than that of the free-recall condition, even though the cognitive load (i.e., recall two stimuli) remained essentially equal to that of the free-recall response condition.

For both directed-attention conditions, recognition performance was better for words presented to the cued ear than for words presented to the noncued ear in almost all subjects (see Figure 1). Dichotic word-recognition performance of the young group for directed-attention right and left conditions was 80–90%, and the resulting ear advantages were small (6.7% REA and 3.6% LEA). For the most part, both older groups exhibited larger ear advantages for the directed-attention conditions than did the young group. The exception was a mean LEA of 2.6% from the 60–69 year group in the directed-attention left condition, which was 1% smaller than the LEA for the young group in the same condition. The small mean LEA observed in the 60–69 year age group most likely reflects a subset of listeners (n = 2) with few to no responses for the left ear in the directed-attention left condition. Superior recognition performance from the cued ear can be attributed to fewer responses from the noncued ear and is consistent with previous research in both young and older adults (Wilson et al, 1968; Asbjørnsen and Hugdahl, 1995; Asbjørnsen and Bryden, 1996; Strouse et al, 2000a, 2000b; Hugdahl et al, 2001).

For both young and older listeners, the observed LEAs from the directed-attention left condition were smaller and more variable than the REAs from the directed-attention right condition (see Table 2). The effect of a smaller LEA was relatively minor for the young group. The effect for the older groups, however, was more pronounced; the LEA for the directed-attention left condition was 28.6% smaller for the 60–69 year group and 9.5% smaller for the 70–79 year group than the REA for the directed-attention right condition. Similar differences between directed-attention conditions have been reported previously (Asbjørnsen and Hugdahl, 1995; Asbjørnsen and Bryden, 1996; Strouse et al, 2000a, 2000b). Strouse et al (2000a), for example, reported a 5% smaller LEA than REA for a group of young listeners and a 17.5% smaller LEA than REA for a group of adult listeners on a dichotic digit directed-attention task. The disproportionate ear advantages between right and left directed-attention conditions offers further evidence of a left-ear disadvantage for dichotic stimuli in older listeners.

Further inspection of the raw data from the present study revealed that three subjects from the older groups exhibited a near-total left-ear disadvantage (see Figure 1). Table 3 presents the dichotic word-recognition data for the three subjects. Each of the three subjects exhibited poor performance on words presented to the left ear for free recall and both directed-attention conditions. These three subjects were unable to improve their recall

Table 3. Dichotic Word Recognition Performance (in percent correct) for a Subset of Older Adult Subjects from the Present Study with Poor Performance on Words Presented to the Left Ear in All Response Conditions

	Free Recall (%)		Directed-Attention Right (%)		Directed-Attention Left (%)	
	Right Ear	Left Ear	Right Ear	Left Ear	Right Ear	Left Ear
Group II (60–69 years)						
Subject 1	79	1	84	0	87	0
Subject 2	67	0	81	0	78	0
Group III (70–79 years)						
Subject 3	65	3	63	3	73	2

of words presented to the left ear even when cued to the left ear. Similar results were reported by Carter et al (2001) in older adult hearing aid users. Listeners in their study were unable to improve their recognition performance on dichotic digits presented to the left ear in the directed-attention condition. The listeners also exhibited difficulty understanding speech in background noise (multitalker babble) and experienced a lack of benefit with bilateral amplification.

Clinical Implications and Future Research

A potential consequence of a left-ear disadvantage observed in older listeners with sensorineural hearing loss may be a lack of benefit in speech understanding from binaural amplification, particularly in the presence background noise. Evidence of auditory processing deficits in adult listeners with sensorineural hearing loss, such as a dichotic left-ear disadvantage, has been associated with unsuccessful use of binaural amplification (Stach et al, 1991; Chmiel et al, 1997; Carter et al, 2001). Such case studies illustrate the importance of identifying those older individuals with a left-ear disadvantage, or more generally, an auditory processing deficit for whom binaural amplification would potentially be problematic or ineffective. Deficits in auditory processing, however, are not easily recognized based on common clinical measures (e.g., pure-tone thresholds and monaural word recognition in quiet). Rather, auditory processing deficits may only be evident when binaural measures of speech recognition, such as dichotic listening, are used (Willott, 1991).

Dichotic speech recognition measures, such as those used in the present study, may offer an effective method of evaluating older listeners in need of alternative rehabilitative strategies, including monaural amplification, the use of directional microphones, or a frequency-modulated system. The potential effectiveness of dichotic listening as a clinical instrument, however, is limited by the small number of case studies that associate a dichotic left-ear deficit with unsuccessful use of binaural amplification. Indeed, the present study did not measure aided benefit or hearing-aid preferences among the older groups with sensorineural hearing loss. Direct assertions regarding alternative rehabilitative strategies, therefore, cannot be made without further study linking a dichotic deficit to reduced benefits from binaural amplification. Future research with dichotic speech recognition measures should incorporate larger samples of older listeners in order to determine the prevalence of a dichotic left-ear disadvantage associated with auditory processing deficits, as well as aided benefit in monaural and binaural listening conditions.

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