Dichotic listening: A predictor of speech-in-noise perception in older hearing-impaired adults?

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The objective of the study was to examine the relations between two auditory processes, dichotic listening and speech perception in noise. Both involve listening to competing signals and significantly decline with age. Dichotic listening and speech identification in multitalker noise were tested in 36 elderly participants with symmetric mild-to-moderate hearing loss. High negative correlations between the SNR levels in which 50% and 30% of the words were correctly identified and the dichotic scores were found. These correlations were attributed to the dichotic score in the non-dominant ear. Our data suggest that dichotic listening, a major processing deficit in hearing-impaired older adults, could potentially serve as a reliable predictor of speech-in-noise perception in this population.

INTRODUCTION

The most common complaint of elderly hearing-impaired individuals is the difficulties in understanding speech in the presence of background noise. These difficulties are more prominent in the presence of competing speech, of either one speaker or (to a larger extent) in the presence of multi-talker babble noise (Divenyi and Haupt, 1997; Schneider and Pichora-Fuller, 2001). These have been attributed to age-related peripheral hearing loss (Humes and Roberts, 1990; Humes, 1996; Killion, 1997), as well as age-related cognitive decline (e.g., Gordon-Salant and Fitzgibbons, 1993; Pichora-Fuller *et al.*, 1995; Martin and Jerger, 2005; Schneider *et al.*, 2005; Tun *et al.*, 2002; Wingfield *et al.*, 2005; Humes *et al.*, 2007), changes in central auditory processes (e.g., Schneider *et al.*, 1994; Frisina and Frisina, 1997; Divenyi and Haupt, 1997; Strouse *et al.*, 1998; Snell and Frisina, 2000; Frisina, 2001; Gordon-Salant and Fitzgibbons, 2001; Schneider and Pichora-Fuller, 2001; Divenyi *et al.*, 2005; Martin and Jerger, 2005), or the combination of cognitive, central, and peripheral causes (Martin and Jerger, 2005).

Dichotic listening, like speech perception in multi-talker noise, is a challenging listening situation because listeners are required to cope with competing speech signals. Studies on dichotic listening provide evidence for age-related changes in central auditory processing. An overall decline in dichotic scores was reported, together with enlarged right-ear advantage (REA) for speech signals due to large reduction in the left-ear dichotic scores (left-ear deficit, LED) (Jerger *et al.*, 1994; Jerger *et al.*, 1995; Noffsinger *et al.*, 1996; Wilson and Jaffe, 1996; Strouse and Wilson, 1999; Strouse *et al.*, 2000; Hallgren *et al.*, 2001; Roup *et al.*, 2006). In

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addition, Dos-Santos *et al.* (2008a,b) showed a decline in REA during dichotic listening in the presence of noise due to higher dichotic scores in the left ear and lower right-ear scores.

It was claimed that the substantial LED in verbal dichotic tasks and the significant right-ear deficit (RED) in non-verbal tasks may have a considerable impact on older adults' ability to use binaural information effectively, including the information which is used for speech identification in noise (Jerger *et al.*, 1995; Strouse-Carter *et al.*, 2001). It was further suggested that dichotic listening and speech perception in noise may be related to each other, since both involve listening to competing signals (Martin and Jerger, 2005), and both decline with age. Moreover, Givens *et al.* (1998) reported a significant correlation between dichotic listening scores and hearing-aid satisfaction. Thus, the aim of the current study was to examine the relations between these auditory processes, and to investigate whether the perceptual difficulties of older hearing-impaired adults in complex listening environments can be predicted using a relatively simple dichotic listening test.

METHODS

Participants: A group of 36 participants who never used hearing aids, ages 64-88 years (mean age in years ± s.d., 76.3 ± 5.9; median, 77 years), 20 men and 16 women, were recruited from an audiology clinic. All participants had a symmetric sensory hearing loss of 30-70 dB at 0.5-4 kHz, with flat or mild-moderate slope audiograms and symmetric speech-recognition scores (PB-50, 86.22 ± 11.64, 85.44 ± 10.77, right ear, left ear, respectively). They were cognitively fit (mini mental state examination, 27.9 ± 1.4; inclusion score: ≥ 24; digit span standard score, 9.4 ± 2.2; inclusion score: ≥ 6). 35 participants were right-handed and one participant left-handed, as tested with the Edinburgh Dexterity questionnaire (Oldfield, 1971).

The participants underwent dichotic monosyllabic words test and tests of speech identification in noise.

Dichotic tests: 6 dichotic lists, each with 25 pairs of phonetically-balanced monosyllabic words, adopted from the Hebrew speech-discrimination test (PB-50), were recorded and digitally normalized for length and intensity using Nuendo 3.2.0 audio software. The test stimuli were presented at each participant's most comfortable level (MCL) through calibrated TDH 39 earphones and a MAICO MA 52 audiometer in a sound-proof room, such that one word of each pair was presented to the right ear, while the other word was presented simultaneously to the left ear. Each pair of dichotic words was preceded with a carrier phrase which was played simultaneously to both ears: "please repeat…". A four-second silent interval was inserted after every dichotic pair to enable the participants to repeat the test words and the experimenter to write them down. Each correctly identified word was scored 4%, and the dichotic score was the sum of the correct scores in each ear. In addition, the total dichotic score was calculated as the sum scores in the two ears.

Speech in noise: 26 lists of 20 bi-syllabic recorded words, based on the Hebrew SRT word lists were used together with multi-talker babble noise which was comprised of

4 Hebrew speakers (2 men and 2 women), all recorded, normalized, and mixed using Nuendo 3.2.0 audio software. The test words were presented at each participant's individual MCL from a loudspeaker located one meter in front of the listener (azimuth 0°) and the babble noise were presented simultaneously from two loudspeakers located one meter from the listener at azimuths +45° and −45°. The word lists and babble noise were presented using MAICO MA 52 audiometer in descending signal-to-noise ratios (SNRs). SNRs were adjusted by changing the level of the noise while keeping the level of the words constant. Levels of SNRs for which each participant recognized 30% and 50% of the words were eventually identified. The 50% level is reported because it is commonly used for threshold estimation (e.g., HINT, Nilsson *et al.*, 1994; QuickSIN, Killion *et al.*, 2004). The 30% level was selected because the average SNR at which this level of performance was achieved in the pre-test (−0.44 dB) represents an SNR for common daily environments (e.g., subway or aircraft, Schneider *et al.*, 2002).

RESULTS

Dichotic listening: Very low dichotic scores were found in both ears. The average scores were 58.8% ± 17.9 in the dominant ear and 37.8% ± 19.7 in the non-dominant ear, thus the average REA was 21%.

Speech identification in noise: the average SNR level, required to reach the 50% level of word identification, was +1.25 dB ± 2.8, and the average SNR level required to reach the 30% level of word identification was −0.44 dB ± 2.3.

Both tests were characterized by large variability among the participants: The dichotic scores ranged from 16% to 88% in the dominant ear, and from 4% to 76% in the non-dominant ear; in the speech identification in noise tests there were differences of up to 10 dB in SNR levels between the participants.

We calculated the Pearson correlations between dichotic performance and achievements in speech identification in noise. High negative correlations were observed between the total dichotic score and the SNR levels at which 50% and 30% of the words were correctly identified ($r = -0.710$, $p < 0.001$ at both levels, see Fig. 1), indicating that in general, listeners with better dichotic scores tended to have better speech identification in noise and vice versa.

In addition, high negative correlation was found between the non-dominant ears' dichotic scores and both SNR levels at which 50% ($r = -0.707$; $p < 0.001$) and 30% ($r = -0.708$, $p < 0.001$) of the words were correctly identified (Fig. 2). Similar correlations were found for the dominant ear ($r = -0.597$, $p < 0.001$ and −0.596, $p < 0.001$, respectively). Nevertheless, when regression models were used to predict the SNR levels required to achieve 50% or 30% word identification, the dichotic score in the non-dominant ear was a significant predictor (50%: $\beta = -.56$, $t = -3.36$, $p = .002$; 30%: $\beta = -.57$, $t = -3.38$, $p = .002$), but those in the dominant ear had no additional contribution (50%: $\beta = .20$, $t = -1.19$, $p = .24$; 30%: $\beta = -.16$, $t = -1.17$, $p = .25$). This latter analysis suggests that the correlations between the total dichotic scores and speech-in-noise identification may result from disruption of dichotic listening and not simply from reduced speech perception in both ears under competing signal conditions.

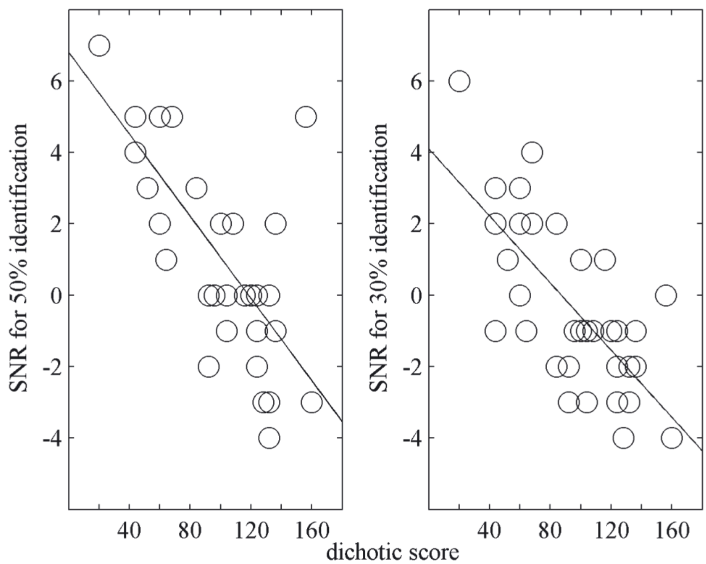

Fig. 1: The relationship between speech identification in noise (50% identification level on the left panel, 30% identification on the right panel) and the total dichotic score. Individual data are shown in circles. Lines show the linear fit between SNRs and dichotic scores.

DISCUSSION

Low achievements were observed in the dichotic listening test, with extremely low scores in the non-dominant ears (LED), making an average REA of 21%. These results are in line with previous studies (e.g., Strouse *et al.*, 2000; Hallgren *et al.*, 2001; Roup *et al.*, 2006), demonstrating the deficits in processing dichotic words in older adults, as opposed to young normal-hearing listeners that typically score 90%-100% in dichotic listening tests with minimal discrepancies (about 2%) between the ears (Roup *et al.*, 2006).

In the speech-in-noise tests high SNR levels were required to identify both 50% and 30% of the words, demonstrating the difficulties hearing-impaired older adults may face in common daily environments (Frisina and Frisina, 1997; Gordon-Salant, 2005; Martin and Jerger, 2005).

There was a large variability in the dichotic scores and in speech identification in noise. Inter-subject variability is one of the main characteristics of the elderly population in general, and particularly of hearing-impaired older adults. This variance is apparent in various hearing and auditory-processing tests and has a major role in the differences among individuals in hearing-aid acclimatization and satisfaction (Humes and Nelson, 1991; Gordon-Salant and Sherlock, 1992; Humes *et al.*, 1994; Roup *et al.*, 2006).

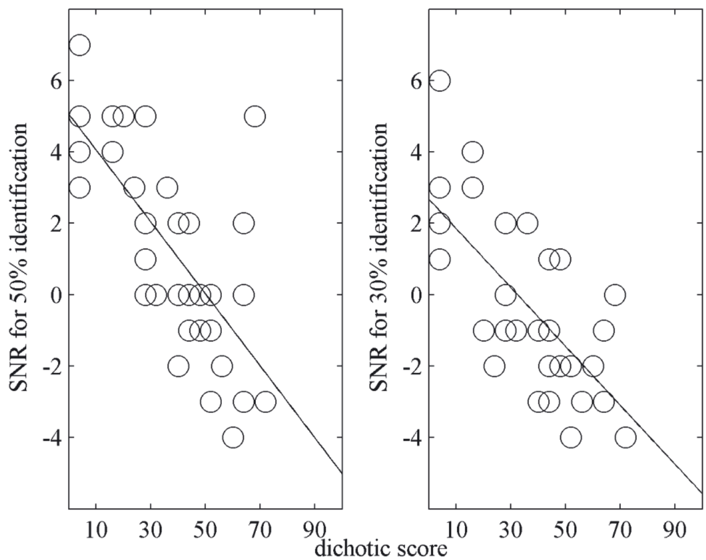

Fig. 2: The relationship between speech identification in noise and the non-dominant ear dichotic score. For further details see Fig. 1.

Low dichotic scores with large LED and low scores in speech identification in multi-talker babble noise both reflect deficits in the ability of the auditory system to process competing speech stimuli. Indeed, we found high correlations between speech-in-noise scores and dichotic scores of the non-dominant ear, the dominant ear, and the total dichotic scores: Participants who had lower dichotic achievements tended to require better signal-to-noise ratios to identify the test words. These results support the claims made by Jerger *et al.* (1995) and Strouse-Carter *et al.* (2001) that deterioration in dichotic listening may be significant in elderly people's capability to separate target speech from competing spatially-separated speech stimuli. Moreover, deterioration in dichotic listening may result in lower satisfaction with hearing aids (Chmiel and Jerger, 1996; Givens *et al.*, 1998).

Speech in noise is routinely measured by no more than 25% of audiologists in the course of hearing-aid fitting (Weinstein, 2013). Dichotic listening is easy and fast to evaluate. Our results suggest that dichotic listening tests may be a good predictor for individuals' abilities to understand speech in the presence of multi-talker noise, and thus can serve as an available and reliable tool in hearing rehabilitation counseling.

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