Binaural Interference and the Effects of Age and Hearing Loss

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Abstract

Background: The existence of binaural interference, defined here as poorer speech recognition with both ears than with the better ear alone, is well documented. Studies have suggested that its prevalence may be higher in the elderly population. However, no study to date has explored binaural interference in groups of younger and older adults in conditions that favor binaural processing (i.e., in spatially separated noise). Also, the effects of hearing loss have not been studied.

Purpose: To examine binaural interference through speech perception tests, in groups of younger adults with normal hearing, older adults with normal hearing for their age, and older adults with hearing loss.

Research Design: A cross-sectional study.

Study Sample: Thirty-three participants with symmetric thresholds were recruited from the University of Iowa community. Participants were grouped as follows: younger with normal hearing (18–28 yr, n = 12), older with normal hearing for their age (73–87 yr, n = 9), and older with hearing loss (78–94 yr, n = 12). Prior noise exposure was ruled out.

Data Collection and Analysis: The Connected Speech Test (CST) and Hearing in Noise Test (HINT) were administered to all participants bilaterally, and to each ear separately. Test materials were presented in the sound field with speech at 0° azimuth and the noise at 180°. The Dichotic Digits Test (DDT) was administered to all participants through earphones. Hearing aids were not used during testing. Group results were compared with repeated measures and one-way analysis of variances, as appropriate. Within-subject analyses using pre-established critical differences for each test were also performed.

Results: The HINT revealed no effect of condition (individual ear versus bilateral presentation) using group analysis, although within-subject analysis showed that 27% of the participants had binaural interference (18% had binaural advantage). On the CST, there was significant binaural advantage across all groups with group data analysis, as well as for 12% of the participants at each of the two signal-to-babble ratios (SBRs) tested. One participant had binaural interference at each SBR. Finally, on the DDT, a significant right-ear advantage was found with group data, and for at least some participants. Regarding age effects, more participants in the pooled elderly groups had binaural interference (33.3%) than in the younger group (16.7%), on the HINT. The presence of hearing loss yielded overall lower scores, but none of the comparisons between bilateral and unilateral performance were affected by hearing loss.

Conclusions: Results of within-subject analyses on the HINT agree with previous findings of binaural interference in ≥17% of listeners. Across all groups, a significant right-ear advantage was also seen on the DDT. HINT results support the notion that the prevalence of binaural interference is likely higher in the elderly population. Hearing loss, however, did not affect the differences between bilateral and better unilateral scores. The possibility of binaural interference should be considered when fitting hearing aids to listeners with symmetric hearing loss. Comparing bilateral to unilateral (unaided) performance on tests such as the HINT may provide the clinician with objective data to support subjective preference for one hearing aid as opposed to two.

Key Words: aging, hearing aids, hearing loss, speech perception

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Abbreviations: ANOVA = analysis of variance; CST = Connected Speech Test; DDT = Dichotic Digits Test; HINT = Hearing in Noise Test; OHI = older with hearing impairment; ONH = older with normal hearing for their age; rau = rationalized arcsine units; SBR = signal-to-babble ratio; SNR = signal-to-noise ratio; SNR-50 = signal-to-noise ratio that yields 50% correct speech recognition; SRT = speech reception threshold; YNH = younger with normal hearing

INTRODUCTION

The advantages of listening with two ears as opposed to one have long been established (Koenig, 1950; Akeroyd, 2006). They include improved sound localization (Middlebrooks and Green, 1991), improved speech perception in background noise due to the squelch effect (Kock, 1950), and loudness summation (Keys, 1947). It is generally assumed that listening with two ears is always preferable, and consequently, that listeners with bilateral hearing loss should be fit with two hearing aids. However, this common belief was challenged in the mid-1990s by case reports of binaural interference. Binaural interference in the context of the present investigation refers to the situation wherein performance with two ears is poorer than with the better ear alone (note that the term "binaural interference" has also been used with regard to spectral interference effects on binaural cues used for sound localization [McFadden and Pasanen, 1976]). Those small-scale studies used mostly speech perception (in quiet and in noise) and electrophysiological measures to explore underlying reasons for unsuccessful bilateral hearing aid use in spite of fairly symmetric hearing thresholds (Jerger et al, 1993; Chmiel et al, 1997; Carter et al, 2001; Holmes, 2003).

This first documentation of the existence of binaural interference fueled interest in further exploration of the phenomenon in larger groups of listeners. Allen et al (2000) reported better bilateral speech reception thresholds (SRTs) than the better unilateral SRT in all but the older hearing-impaired group (no interference reported). Speech perception with W-22 words in the bilateral and unilateral conditions showed no evidence of binaural advantage or interference. Within-subject analyses using confidence intervals revealed that two participants had binaural interference and one had advantage (all belonging to one of the older age groups). The authors argued that the number of individuals with binaural interference in their sample is close to what would be expected by chance. However, testing speech perception in quiet as opposed to in background noise may not have been conducive to binaural processing.

In contrast, Walden and Walden (2005) found better performance in noise with amplification in the better-performing ear than with amplification in the poorer-performing ear and bilaterally (i.e., binaural interference). In 82% of their elderly veterans, bilateral amplification yielded greater signal-to-noise ratio (SNR) loss (i.e., poorer performance) than amplification in either ear alone. No differences between the ears were found on the Dichotic Digits Test (DDT). One potential issue with this study was that their presentation levels of 70 dB HL (82 dB SPL) in the sound field could have been too high, possibly causing the hearing aids to distort. Also, because the contralateral ear canal was open during unilateral testing, for many participants the speech and noise levels could have been audible to that ear too (as later confirmed by McArdle et al, 2012).

Similar binaural interference results were reported by Henkin et al (2007) for monosyllabic word recognition in noise at +10 dB SNR (speech at 0°, noise at 180°), with 71% of the listeners having better word recognition with one hearing aid as opposed to two (significance not reported). Contrary to the findings of Walden and Walden (2005), a dichotic sentence test revealed a significant right-ear advantage, but the investigators found no relationship between the right-ear advantage and the binaural reduction in performance.

Given the unexpected results found by Walden and Walden (2005), McArdle et al (2012) replicated that study, verifying that the hearing aids were not distorting for the inputs used and obtaining subjective loudness ratings for the high-level inputs. They found no evidence of binaural interference (or advantage) with group results. Only 20% of the listeners performed better with one hearing aid than bilaterally (as opposed to 82% in the original study). In a second experiment, speech perception in noise was assessed via earphones at 70 dB HL, eliminating potential confounds from the hearing aids. The two bilateral conditions yielded better performance than with either ear alone. This was also true for 65% of the participants, with individual data analysis. Still, the authors note that in both their experiments, ~20% of the participants performed better in noise with a single ear.

A potential confounder in some of the studies reviewed could be the use of hearing aids by the participants during testing (Walden and Walden, 2005; Henkin et al, 2007). While providing an ecologically valid testing condition, digital processing in hearing aids can introduce subtle time delays to the auditory signal delivered to the ear. If the processing delay is not the same in the two hearing aids worn by a given listener, binaural hearing may be hindered. It is known that binaural processing relies on very precise timing/phase differences between the sounds that arrive at the two ears (Middlebrooks and Green, 1991). Another potential confounder in previous studies is the lack of spatial separation between speech and noise, by presenting both through a single loudspeaker (Walden and Walden, 2005). To afford participants the possibility of binaural hearing during speech perception in noise, spatial separation between the two is important.

Finally, the use of veterans as the participant population could also have potentially impacted previous findings (Walden and Walden, 2005; McArdle et al, 2012). Besides consisting of mostly males, those listeners in general have hearing loss that is at least partially due to noise exposure. The configuration of noise-induced hearing loss is similar to what would be expected from other etiologies such as genetics or aging; however, the effects of noise exposure in the auditory system seem to go beyond the loss of cochlear hair cells. Evidence from animal models suggests that the effects of noise exposure (especially at an early age) continue for years after the end of exposure in that auditory nerve fibers are lost, unlike observations in aged control animals (Kujawa and Liberman, 2006).

Still, although previous studies have had limitations and thus provided weak support for binaural interference with group analyses, the evidence suggests that binaural interference exists in at least a proportion of listeners. Thus, considering the possibility of binaural interference is important for hearing aid fitting. Recent data show that nearly 85% of hearing aid fittings in the United States are bilateral (Strom, 2014). However, there is evidence that many users prefer wearing only one hearing aid. A large retrospective survey of hearing aid users who were likely to benefit from bilateral hearing aids showed that 31% of them preferred a single hearing aid (Boymans et al, 2009). Likewise, in a prospective study involving a structured 3-mo trial with bilateral amplification, a striking 46% of listeners with symmetric hearing loss preferred using one hearing aid (Cox et al, 2011). This has prompted researchers to examine which factors or tests, if any, can predict future unilateral hearing aid use in listeners with symmetric hearing loss. While a few significant predictors of unilateral/bilateral hearing aid use have been reported (Köbler et al, 2010; Cox et al, 2011), one study failed to find such predictors among a test battery administered before fitting (Boymans et al, 2008). Several other factors such as cosmetics, cost, and poor manual dexterity may underlie the preference for one hearing aid and pose a confounding variable in those studies. Yet, better performance with a single hearing aid as opposed to two seems to be an important factor for unilateral hearing aid use (Cox et al, 2011), suggesting that there may be a physiologic mechanism such as binaural interference in play.

It is noteworthy that many of the binaural interference cases reported seem to be found in the elderly population. Older adults in general have difficulty understanding speech in challenging listening situations such as in background noise or in the presence of reverberation (CHABA, 1988). In addition, older adults seem to have diminished temporal processing abilities, as demonstrated in studies of gap detection and temporal order discrimination/identification (Humes et al, 2012). However, many highly functioning older adults are able to compensate for speech perception difficulties by using contextual support (Pichora-Fuller et al, 2007), and/or by activating additional areas in the brain (Wong et al, 2009). Thus, it might be expected that many older adults would have similar binaural processing to their younger counterparts.

This study was conducted in an effort to further explore the phenomenon of binaural interference, which is one possible underlying reason for subjective preference for a single hearing aid. However, due to potential confounds introduced by the hearing aids themselves, testing conditions in this study did not involve hearing aids. The aim of the present study was to investigate the occurrence of binaural interference in groups of younger and older adults, and the effects of hearing loss in the older age group. Prior noise exposure was ruled out. Because previous studies suggest that the prevalence of binaural interference may not be high enough to be evident with group analyses, within-subject analyses were also performed. It was hypothesized that binaural interference would be found for a portion of the participants in the within-subject analyses, mostly in the older age groups.

METHODS

Participants

Thirty-three listeners participated in this study, divided into three groups: younger with normal hearing (YNH; n = 12, age range = 18–28 yr, mean = 22 yr, seven females), older with normal hearing for their age (ONH; n = 9, age range = 73–87 yr, mean = 80.2 yr, seven females), and older with hearing impairment (OHI; n = 12, age range = 78–94 yr, mean = 83.2, five females). Pure-tone thresholds were obtained for the octave frequencies between 250 and 8000 Hz, including the interoctave frequencies of 3000 and 6000 Hz. The average of normal-hearing thresholds for age (in reference to ISO, 2000) for the older age group is depicted in Figure 1 by the long dashed line. Hearing loss was primarily sensorineural, that is, no air-bone gaps >10 dB were allowed. Normal middle-ear function was confirmed with immittance measures.

Figure 1 shows the average hearing thresholds for the elderly groups; symbols connected by solid lines represent the ONH group, and symbols connected by dashed lines represent the OHI group. Thresholds for the YNH group were 10 dB or better across all frequencies (not shown). All participants exhibited symmetric

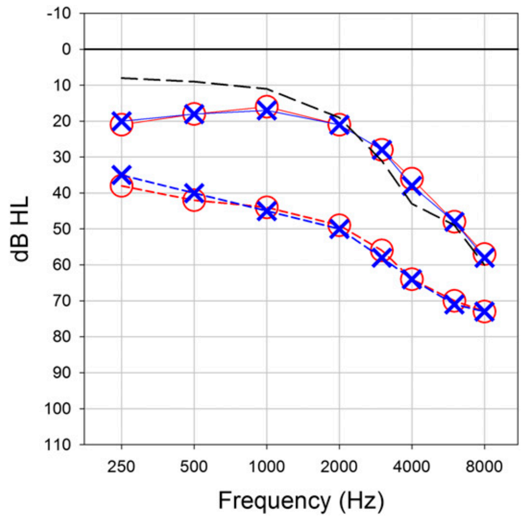

Figure 1. Average hearing thresholds for the ONH and OHI groups are represented by symbols connected by solid and dotted lines, respectively. The average of normal-hearing thresholds for the elderly participants is depicted by the dashed line (in reference to ISO, 2000). (This figure appears in color in the online version of this article.)

thresholds, defined as no more than a 15-dB difference between the two ears at any frequency. Participants were recruited from clinic records, department personnel, and retirement residences. All participants were paid for their participation. Data collection lasted ~2.5 hr, over one or two sessions. This study was approved by the University of Iowa Institutional Review Board.

Procedures

Following informed consent procedures, participants underwent a brief assessment of their medical and otological history. Individuals presenting with conditions that could potentially interfere with hearing and auditory processing, such as noise exposure, head trauma, ototoxicity, and/or known genetic factors, were excluded from this study. Four participants were excluded based on their medical history and/or audiometric configuration.

The Mini-Mental State Examination (Folstein et al, 1975) was administered to all participants as a screening tool of cognitive functioning. Mini-Mental State Examination scores decrease with age, which is consistent with a greater incidence of cognitive impairments in the elderly. Therefore, passing criteria were based on the 25th percentile scored by the normative population in each age group (Crum et al, 1993). All participants scored at or above the cutoff score.

Speech Perception

All testing was carried out in a double-walled, sound-treated IAC booth (Industrial Acoustics Company, North Aurora, IL). Speech recognition was tested in three conditions: right ear only, left ear only, and bilaterally. Speech perception materials were presented through Grason-Stadler 1700-2002 loudspeakers (Grason-Stadler, Eden Prairie, MN), with speech coming from 0° azimuth and the competing noise from 180°. When testing unilaterally, the opposite ear was plugged with a compressible foam earplug. Participants were seated equidistantly from both loudspeakers at 0.8 m and were instructed to keep their heads straight facing the front loudspeaker. Practice items were presented to participants before testing began. The presentation order of tests and conditions across participants was counterbalanced.

The Hearing in Noise Test (HINT) (Nilsson et al, 1994) is an adaptive test seeking the signal-to-noise ratio that yields 50% correct speech recognition (SNR-50). Speech materials consist of sentences in a spectrally matched noise background. The participant's task was to repeat each of 20 sentences (two lists), as spoken by a male talker. The noise remained fixed at 65 dBA, while the speech level was varied in 4-dB steps (for the first five sentences) and 2-dB steps (for the remaining sentences), according to the participant's performance. To derive the SNR-50, presentation levels for sentences 5–20 were averaged and subtracted from the presentation level of the noise.

The Connected Speech Test (CST; Cox et al, 1987) was used to assess speech intelligibility in noise. It consists of a large number of passages about familiar topics, with ten sentences per passage topic. The speech is presented in a background of multitalker babble, at a fixed signal-to-babble ratio (SBR). In this study, two different SBRs were used: +2 dB, which was deemed to be a fairly easy listening environment for both normal-hearing and hearing-impaired participants, and −2 dB, which was intended to be more difficult. The speech was fixed at 63 dB SPL at ear level for normal-hearing listeners and at 30 dB SL relative to the average of 1000- and 2000-Hz thresholds for hearing-impaired listeners. Presentation levels were slightly adjusted based on subjective report, and were kept constant throughout testing. The participants' task was to repeat as much of each sentence as possible. Key words (25 per passage) were scored for a total percent correct. For each ear condition, 4 passages were presented, totaling 24 passages (4 passages × 2 SNRs × 3 ear conditions—bilaterally and unilaterally left and right). To avoid further frustration, whenever participants scored ≤25% correct, only two passages were presented per ear condition. When this happened at the +2 dB SBR, passages were not presented at −2 dB SBR. As a result, the −2 dB SBR condition was not presented to 3 of the 12 older hearing-impaired individuals.

The HINT and the CST were chosen due to their high reliability and small training effects. In addition, the CST has abundant contextual cues that are representative of everyday communication.

DDT

The DDT (Musiek, 1983) was used to assess the ability of binaural separation, which can lead to the expression of binaural interference. In this test, different digits from 1 to 10 (excluding 7, as it is the only nonmonosyllable digit) are presented simultaneously to both ears. Two paradigms can be used with the DDT: "free recall," when the listener is instructed to repeat all the digits heard and "directed recall," when the listener is to repeat only the digits presented to the precued ear. The free-recall paradigm can be more affected by cognitive functioning, as it places a heavier load on memory. Therefore, as auditory processing was the main focus of this study, only the directed-recall paradigm was used.

The DDT has high intertest reliability, both for younger and elderly listeners (Strouse and Wilson, 1999a), and the results do not appear to be significantly affected by hearing loss. Although brain-processing asymmetries would predict a slight right-ear advantage on the DDT (and on dichotic tests in general), larger asymmetries have been taken as a sign of binaural interference. A right-ear asymmetry of 2.9–4% has been reported in younger listeners in dichotic listening tests with verbal stimuli, while in older listeners, this asymmetry seems to grow larger, up to 40% (Jerger, 2001).

DDT materials consisted of tracks 7 and 8 from the compact disc "Tonal and Speech Materials for Auditory Perceptual Assessment, Disc 2.0" (Department of Veterans Affairs, 1998). Each track has 54 interleaved one-, two-, and three-pair digits that are presented to each ear through earphones, in quiet. Digits were presented at 50 dB SL relative to the SRT with spondees (as suggested by Musiek and Pinheiro, 1985; Bellis, 2003). For hearing-impaired individuals, when this level was reported to be too loud, it was slightly reduced.

RESULTS

Group Analyses

Group mean scores were compared between the left unilateral, right unilateral, and bilateral conditions across the three groups. HINT SNR-50 values were analyzed with a repeated-measures analysis of variance (ANOVA) in a mixed-model framework, with group as the between-subjects factor and ear condition (left, right, bilateral) as the within-subjects factor. In this test, larger SNR-50 values indicate poorer performance. Results revealed a significant main effect of group [$F_{(2,60)} = 46.29$; $p < 0.0001$], with the older hearing-impaired group having the poorest average SNR-50 across the three ear conditions (5 dB), followed by the ONH group (0.6 dB) and the YNH group (−2 dB). The follow-up comparisons with Bonferroni corrections for multiple tests suggested that each of the three groups was significantly different from the other two. The main effect of the test ear was not significant [$F_{(2,60)} = 0.68$; $p = 0.51$], nor was there a significant interaction between ear and group [$F_{(4,60)} = 0.27$; $p = 0.89$], suggesting that the absence of an ear effect holds for all three groups. HINT scores per group and ear condition are shown in Figure 2A.

The distribution of CST raw percentage scores was first normalized with the logit transformation. In this procedure, percentages are converted into proportions, which are then used to calculate the logarithm of the odds ratio. Transformed scores were analyzed in a mixed-model, repeated-measures ANOVA, with group as the between-subjects factor and test ear (left, right, bilateral) and SBR (+2 dB SBR, −2 dB SBR) as within-subjects factors. The three main effects were significant: group [$F_{(2,30)} = 90.30$; $p < 0.0001$], ear [$F_{(2,60)} = 6.08$; $p = 0.004$], and SBR [$F_{(1,27)} = 69.74$; $p < 0.0001$]. Follow-up testing with Bonferroni corrections revealed that the mean logit-transformed score for each group across all ear conditions and SBRs was significantly different from that of the other two groups (from worst to best performance: OHI = −1.41, ONH = 0.94, YNH = 2.73). Follow-up tests on the ear effect showed that the bilateral scores were significantly better than either right or left ear (right = 0.66, left = 0.71, bilateral = 1.14), while the difference between the two unilateral conditions was not significant. The SBR effect refers to the logit-transformed scores being significantly better at +2 SBR (1.22) than at −2 SBR (0.42), as expected. No interactions were significant, suggesting that the within-subject effects were consistent across the three

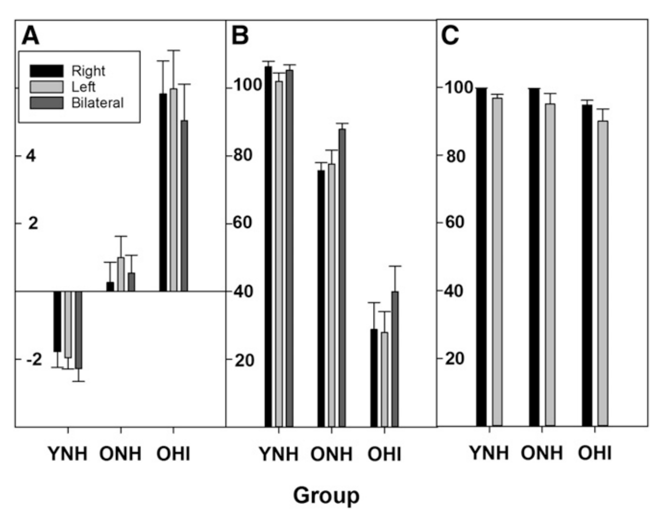

Figure 2. Group mean scores and standard errors are shown, for each ear condition as appropriate (right, left, bilateral). (A) Refers to results of the HINT (in dB SNR-50), where lower numbers represent better performance. (B) Depicts CST results at the +2 SBR condition (in rau). (C) Depicts DDT results (in % correct). In these two tests, higher numbers represent better performance.

groups. Figure 2B displays mean CST scores and standard errors, at the +2 SBR condition. Critical differences for the CST, which were used in the individual data analysis (outlined in "Within-subject Analyses"), are available from the test developers in rationalized arcsine units (rau; Studebaker, 1985). Thus, although the logit transformation was used for group data analysis, the raw CST percentage scores also had to be transformed into rau for comparison with pre-established critical differences. For the sake of consistency, CST scores in Figure 2B are also shown in rau.

The distribution of DDT percentage scores was also normalized with the logit transformation. Scores for left and right ears were pooled across groups and compared with a t test. A significant right-ear advantage was found [$t_{(32)} = 4.83; p < 0.0001$]. A one-way ANOVA on the ear difference score (right ear minus left ear) revealed no significant differences between the three groups [$F_{(2,30)} = 1.54; p = 0.23$], suggesting that the right-ear advantage was present in all groups. For the sake of clarity, DDT scores and standard errors are depicted as percent correct in Figure 2C.

Within-Subject Analyses

Given that the prevalence of binaural interference has been estimated to be as low as 10% (Jerger et al, 1993), it might be expected that its effects would not be evident in group means. Thus, a within-subject analysis was performed, comparing the difference between each participant's bilateral and better unilateral scores to pre-established 95% critical differences for each test.

HINT individual bilateral minus the better unilateral scores are displayed in Figure 3, for each group. The dashed lines represent the critical difference (±1.5 dB) (Nilsson et al, 1994). Recall that on the HINT, higher SNR values indicate poorer performance. Figure 3 shows that the difference scores of 9 of 33 participants (27%) exceeded the critical difference in the direction of interference (top part of the graph), while 6 participants (18%) had binaural advantage (bottom part of the graph).

The individual CST difference scores (in rau) were also compared to critical differences of 14 rau for the normal-hearing participants (Cox et al, 1987) and 15.5 rau for hearing-impaired participants (Cox et al, 1988). Figure 4 depicts the bilateral minus better unilateral scores for individual participants in each group, at +2 dB SBR. Here, higher numbers indicate better performance. Participants whose scores exceeded the critical difference above the dashed line had binaural advantage, while those in the bottom part had binaural interference. At +2 dB SBR, a significant binaural advantage was found in 12% (n = 4) of the participants, and significant interference in 3% (n = 1). This individual belonged to the OHI group. Of the participants tested at −2 dB SBR, binaural advantage was seen in 13% (n = 4) and interference in 3.3% (n = 1) (condition not shown). This individual belonged to the YNH group.

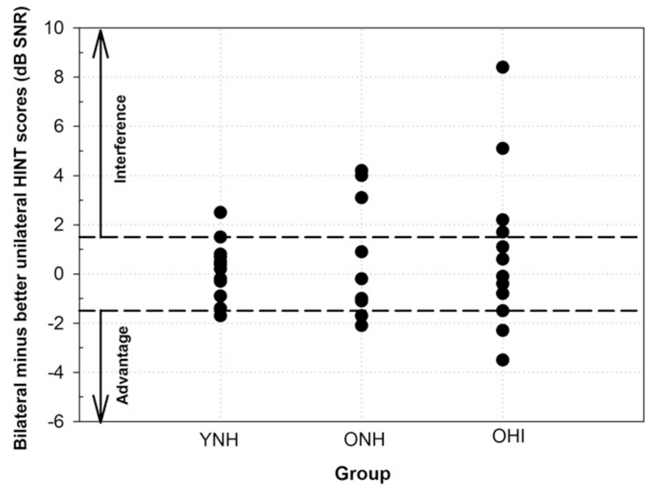

Figure 3. Individual bilateral minus better unilateral HINT scores (in dB SNR), for participants in each group. Pre-established critical differences for this test are represented by the dotted line.

Finally, critical differences were not available for the directed-recall presentation of the DDT. There are published normative data from 30 participants in each group spanning a 10-yr age range from 20 to 79 yr (Strouse and Wilson, 1999b). However, the fact that 39% of those participants showed below-normal performance in the free-recall condition while having normal performance in the directed-recall condition suggests that their deficit is possibly in the cognitive domain. Therefore, this participant group did not seem to provide an adequate basis for comparison with the present groups. Thus, no statistical analysis of individual DDT

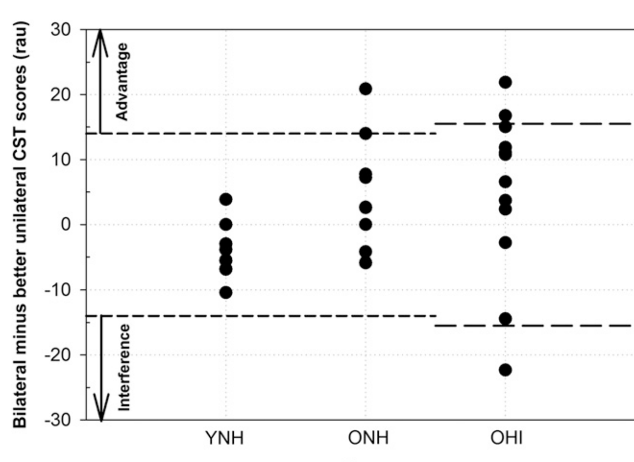

Figure 4. Individual bilateral minus better unilateral CST scores (in rau), for participants in each group, at the +2 SBR condition. Pre-established critical differences for this test are represented by the different dotted lines, for normal-hearing and hearing-impaired listeners.

data was performed. However, individual right- minus left-ear DDT scores can be inspected in Figure 5. It is evident that at least some participants display a large right-ear advantage. A right-ear advantage on the DDT, although expected as a result of hemispheric specialization (Kimura, 1961), has also been taken as a sign of binaural interference (Carter et al, 2001; Jerger, 2001).

DISCUSSION

The purpose of this study was to examine the occurrence of binaural interference in groups of younger adults with normal hearing, older adults with normal hearing for their age, and older adults with symmetric hearing loss. Participants were tested using speech perception tasks in the sound field, each ear separately (with the contralateral ear plugged) and bilaterally, without the use of hearing aids. Results varied across test. On the HINT, the group analysis showed no effect of ear tested, while within-subject analysis showed that 27% of the participants had binaural interference (18% had binaural advantage) when considering critical difference values. A different pattern of results emerged with the CST, which showed a significant binaural advantage across all groups in the means analysis. Individual results showed that, similar to the HINT, a small proportion of participants had binaural advantage (12%) at each SBR. However, only one participant had binaural interference at each SBR. Finally, on the DDT, a significant right-ear advantage was found with group data, and for at least some participants when inspecting individual data.

The HINT and CST reveal somewhat contradicting results in the proportion of binaural interference cases (but yet they show similarly low proportions of binaural advantage). It should be noted, however, that the purpose of each test is different. For instance, the HINT investigates the SNR-50. Recall that Walden and Walden (2005) found binaural interference for 82% of their participants using an SNR-50 test, although in replicating that study, McArdle et al (2012) found that only 20% of participants had binaural interference on the Quick Speech-in-Noise Test both with and without hearing aids. This is similar to the present findings of binaural interference in 27% of the participants with the HINT. In the studies that attempted to separate out groups of successful unilateral and bilateral hearing aid users, SRT in noise was a significant predictor in one study (Köbler et al, 2010), but that was not the case in a different report (Boymans et al, 2008). The speech recognition tests used in previous studies of binaural interference were also different from our use of the CST in that the speech materials consisted of single words (Allen et al, 2000; Henkin et al, 2007). Results of those studies did not agree with each other or with the present findings, in that Allen et al (2000) found no binaural interference or advantage with W-22 words in quiet, and Henkin et al (2007) found better unilateral scores on a Hebrew version of the AB test (an open-set test of phonemically balanced monosyllabic words) in +10 dB SNR. In summary, the SNR-50 tests suggest that ~25% of the listeners exhibit binaural interference, while audibility-based tests appear to be dependent on level, background noise, context, and so on.

The present study found a significant right-ear advantage on the DDT across the groups. Individual scores were not statistically analyzed, but visual inspection of the data shows a right-ear advantage for at least some listeners. Dichotic tests were employed in most of the early case reports in support of binaural interference. In larger samples testing dichotic performance, results have been mixed, with reports of no ear difference (Walden and Walden, 2005; with the DDT) and a right-ear advantage (Henkin et al, 2007; with the threshold-of-interference test). When attempting to predict future unilateral/bilateral hearing aid use, conflicting results have also been reported (Köbler et al, 2010; Cox et al, 2011). A right-ear advantage for speech signals is supported by structural models of cerebral asymmetries; as the contralateral pathways to the hemispheres are stronger than the ipsilateral one, and speech is known to be processed in the left hemisphere, a right-ear advantage should be expected (Nicholls, 1998). In the context of binaural interference investigations, a right-ear advantage for speech signals has been considered as a sign of interference, because it indicates that when attention is focused on the right ear, the participant is able to ignore the contralateral stimulus; however, that does not happen when the listener is to attend to the left ear (i.e., there is interference) (Carter et al, 2001; Jerger, 2001). Despite these theories, there have been no published criteria for "normal" and "abnormal" right-ear advantage.

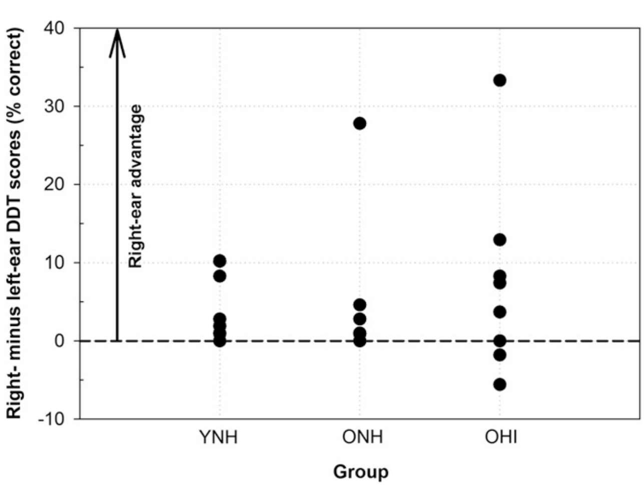

Figure 5. Individual right- minus left-ear DDT scores (in % correct) for participants in each group.

When comparing individual performance across the different tests, of the participants who exceeded the critical differences in the HINT or CST (at either SBR), nine showed interference in one test only (one showed interference in both tests), and five showed advantage in one test only (four showed advantage in both tests). Interestingly, of the two participants with the largest right-ear advantage on the DDT, one also showed significant interference on the HINT, and the other showed interference on both the HINT and CST. Both were older participants, one with normal hearing and one with hearing loss.

Regarding the effects of age, although the groups did not differ on the ear condition (i.e., ear effects, when present, were constant across groups), within-subject HINT results showed that more participants in the elderly groups had binaural interference (33.3%, n = 7) than in the younger group (16.7%, n = 2). The individual CST and DDT analyses are less conclusive on the age effects. On the CST, one participant in the OHI group had interference at +2 SBR and one in the YNH group had interference at −2 SBR. On the DDT, two older participants had a large right-ear advantage, but that was also the case for other participants in each group (to a lesser extent). The means analysis showed a significant right-ear advantage across all groups on the DDT.

The presence of hearing loss in elderly participants produced poorer speech perception scores; however, when comparing bilateral to unilateral performance, hearing loss had no apparent effect on group data. A similar conclusion can be reached with within-subject analyses. On the HINT, 33.3% of participants in the ONH group showed binaural interference (n = 3) and 22.2% showed binaural advantage (n = 2). This was the case for 33.3% (n = 4) and 25% (n = 3) of the participants in the OHI group, respectively. On the CST +2 dB SBR, 55.6% (n = 5) of ONH participants and 75% (n = 9) of OHI participants had significant binaural advantage. On the −2 SBR, the binaural advantage was seen in 66.7% (n = 6) of the ONH listeners and 50% (n = 6) of the OHI listeners. The DDT revealed at least one case of right-ear advantage in each of the elderly groups.

CONCLUSIONS

Taken together, the present results support the occurrence of binaural interference in at least 16.7% of listeners. Hearing loss does not seem to compound the presence of binaural interference. Our findings do provide evidence that binaural interference may be more prevalent in older adults; however, more research in this topic is clearly needed. More direct clinical applications should also be investigated, testing the predictive power of the HINT and DDT in uncovering binaural interference in listeners with reported difficulties with two hearing aids.

The possibility of binaural interference need not change the general practice of bilateral hearing aid fittings for listeners with symmetric hearing loss. However, it is imperative that clinicians be aware of binaural interference and be attentive to its signs, such as subjective reports of preference for one hearing aid. Although potentially deleterious consequences of unilateral fittings such as auditory deprivation should be carefully weighted, bilateral speech testing with adaptive levels of background noise such as with the HINT may provide an objective confirmation of the patient's testimony.

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