J Am Acad Audiol 11: 494–500 (2000)

Investigation of Binaural Interference in Normal-Hearing and Hearing-Impaired Adults

Rose L. Allen*
Brady M. Schwab*
Jerry L. Cranford*
Michael D. Carpenter*

Abstract

When speech recognition testing is performed under diotic conditions, some elderly persons with asymmetric hearing loss exhibit a phenomenon in which the performance of the poorer ear interferes with that of the better ear. This binaural interference phenomenon has been estimated to occur in 8 to 10 percent of elderly hearing aid users. The purpose of the present study was to investigate the prevalence of this phenomenon in groups (n = 12) of young and elderly listeners with normal hearing, plus groups of elderly listeners with hearing loss who were aided or unaided. Of 48 subjects tested, only 2 exhibited significant evidence of binaural interference, a result that is close to that expected by chance. Although both of these subjects were elderly, one had normal hearing and the other was aided binaurally. A third elderly unaided subject exhibited a significant binaural advantage. Further studies are needed to determine the prevalence of binaural interference in normal-hearing or hearing-impaired listeners in any decade of life.

Key Words: Adults, binaural interference, confidence levels, hearing loss, normal hearing, word recognition scores

Abbreviations: ANOVA = analysis of variance, HFPTA = high-frequency pure-tone average of hearing levels at 1000, 2000, and 4000 Hz, OA = older aided hearing-impaired adults, OHI = older unaided hearing-impaired adults, ON = older normal-hearing adults, SRT = speech reception threshold, WRS = word recognition score, YN = young, normal-hearing adults

Binaural interference is an auditory phenomenon that occurs when, in the presence of bilateral hearing loss, the performance of the poorer ear has degrading effects on the performance of the better ear under diotic listening conditions. This phenomenon has been investigated by Arkebauer et al (1971), Jerger et al (1993), and Chmiel et al (1997). Arkebauer et al studied the occurrence of binaural interference in 10 cases of bilateral asymmetric hearing loss. These authors theorized that binaural interference caused word recognition scores (WRSs) to be decreased for the binaural condition when compared to the better ear score alone, due to the interaction of the signals. The study examined differences in WRSs in four conditions: poorer ear under headphone, better ear under headphone, sound field with ears unoccluded, and sound field with poorer ear occluded. In 8 of 10 cases, there was a 2 to 18 percent improvement in WRSs with the poorer ear occluded. In no case did the occlusion of the poorer ear cause a decrease in WRSs.

More recently, based on a sample of 37 subjects, Jerger et al (1993) estimated the prevalence of binaural interference to be roughly 8 to 10 percent among elderly hearing aid users. In this same study, Jerger et al examined evidence of binaural interference in four individuals. In contrast to the Arkebauer et al (1971) study, the Jerger et al subjects had symmetric pure-tone

*Department of Communication Sciences and Disorders, East Carolina University, Greenville, North Carolina
Reprint requests: Rose L. Allen, Department of Communication Sciences and Disorders, East Carolina University, Greenville, NC

Table 1 Means, SDs, and Ranges of High-Frequency Pure-Tone Averages (1000, 2000, and 4000 Hz) by Group

Group	Mean (in dB HL)	SD	Minimum (in dB HL)	Maximum (in dB HL)	Range
YN	6.60	1.61	4.17	9.17	5.00
ON	27.15	7.13	18.33	38.33	20.00
OHI	43.96	4.99	37.50	53.33	15.83
OA	53.68	14.15	31.67	74.17	42.50

YN = young normal, ON = older normal, OHI = older hearing impaired, OA = older aided.

thresholds. These investigators found evidence of binaural interference in electrophysiologic and behavioral measures. Two of the four subjects demonstrated binaural interference through decreased WRSs when aided binaurally versus monaurally. Three subjects had substantially poorer binaural middle latency evoked responses, and one subject showed binaural interference when presented with the Cued-Listening Task (Jerger and Jordan, 1992). Chmiel et al (1997) also described the case of an elderly female with symmetric hearing loss who exhibited binaural interference when synthetic sentences were presented in a binaurally aided condition.

Jerger (1994) has theorized that monaural amplification leads to auditory deprivation that, when not treated by additional amplification, becomes permanent and presents itself as binaural interference. He also stated that "at the first sign of binaural hearing loss it is critical to fit binaural amplification. The longer the loss in either ear is ignored, the more deterioration there will be in speech processing ability" (p. 29). This prediction was recently supported in an excellent study by Hurley (1999). It is important

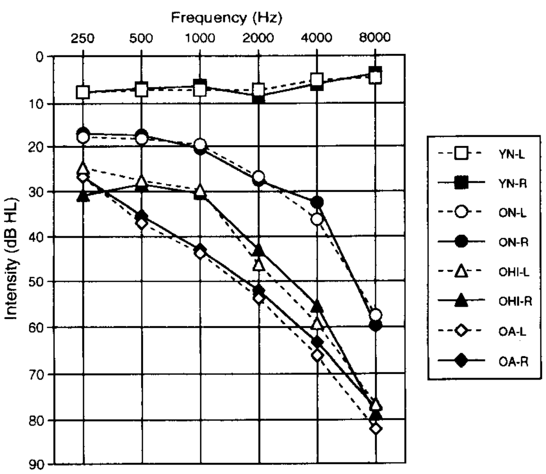

Figure 1 Average pure-tone thresholds for each ear by group. YN = young normal, ON = older normal, OHI = older hearing impaired, OA = older aided.

to note that the aforementioned studies addressed the occurrence of binaural interference in hearing-impaired individuals with either symmetric or asymmetric hearing loss. Two of the four subjects in the Jerger et al (1993) study also had involved medical histories (i.e., viral encephalitis and left-sided cerebrovascular insult) where auditory processing may have been affected by physiologic manifestations.

The present study was undertaken to determine if binaural interference occurs in normal-hearing individuals and in hearing-impaired individuals, regardless of amplification status or age, and who also have no significant medical involvement.

METHOD

Subject Selection

Twelve subjects in each of four groups were examined: young normal (YN)-hearing adults (mean = 22.9 years; range = 20–24), older normal (ON)-hearing adults (mean = 76.4 years; range = 65–86), older unaided hearing-impaired (OHI) adults (mean = 79.7 years; range = 61–93), and older aided (OA) hearing-impaired adults (mean = 81.1; range = 65–89). The OA group consisted of six adults fit monaurally and six adults fit binaurally. Subjects were excluded if they had any history of significant otologic involvement, had abnormal middle ear function (ASHA, 1990), or failed the Mini-Mental State screening (Folstein et al, 1975).

YN adults had hearing threshold levels better than or equal to 25 dB HL from 500 to 4000 Hz, bilaterally. As shown in Table 1, the mean high-frequency pure-tone average (HFPTA) of 1000, 2000, and 4000 Hz for the ON adults was 27.15 dB HL. All hearing-impaired subjects had HFPTAs that exceeded 40 dB HL in at least one ear with no more than a 15-dB difference between ears at more than one frequency. The hearing threshold data for each group are shown in Table 2 and are graphically displayed in Figure 1.

Table 2 Means, SDs, and Ranges of Pure-Tone Thresholds for Right (RE) and Left (LE) Ears by Group

	Frequency (Hz)											
	250		500		1000		2000		4000		8000	
Group	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE	RE	LE
YN												
Mean (dB HL)	7.5	7.5	6.7	7.1	6.3	7.1	8.3	7.1	5.9	5.0	3.8	4.6
SD	3.4	3.4	4.4	4.0	3.1	2.6	3.3	6.2	2.0	4.3	4.3	5.8
Range (dB HL)	10.0	10.0	15.0	15.0	10.0	5.0	10.0	25.0	5.0	15.0	10.0	20.0
ON												
Mean (dB HL)	17.1	17.9	17.5	18.3	20.4	19.6	27.5	26.7	32.5	36.3	59.6	57.5
SD	4.0	5.8	6.6	7.5	9.6	8.9	10.3	10.1	12.0	10.5	27	25.4
Range (dB HL)	15.0	15.0	20.0	30.0	30.0	30.0	30.0	35.0	40.0	25.0	80.0	90.0
OHI												
Mean (dB HL)	30.8	24.6	28.3	27.5	30.4	29.6	42.9	46.3	55.4	59.2	78.8	76.7
SD	7.9	5.8	8.1	6.9	10.3	11.6	8.1	7.4	11.6	10.4	11.9	12.7
Range (dB HL)	30.0	20.0	30.0	25.0	35.0	45.0	25.0	25.0	35.0	40.0	40.0	45.0
OA												
Mean (dB HL)	26.7	26.7	35.4	37.1	42.9	43.8	52.1	53.8	63.3	66.3	77.5	82.1
SD	6.5	9.4	17.3	17.4	17.3	17.9	15.0	17.3	12.9	14.3	9.7	11.4
Range (dB HL)	20.0	35.0	55.0	50.0	55.0	50.0	50.0	55.0	35.0	45.0	35.0	30.0

YN = young normal, ON = older normal, OHI = older hearing impaired, OA = older aided.

Equipment

Subjects were tested in a sound-treated suite. A Grason-Stadler 61 (GSI 61) clinical audiometer was used for routing pure-tone and recorded speech stimuli to EAR Tone 3A insert phones. A Sony CDP-CE415 compact disc player was used to present recorded speech materials. A Grason Stadler 33 (GSI 33) middle ear analyzer was used to test middle ear function.

Procedures

Pure-tone thresholds (250–8000 Hz), tympanograms, speech recognition thresholds (SRTs; ASHA, 1988), and WRSs (30 dB SL re: SRT) were obtained for each ear. Binaural SRTs and WRSs (30 dB re: binaural SRT) were also obtained. Speech audiometry used spondaic words and Central Institute for the Deaf W-22 monosyllabic word lists (1A–4A). Word lists consisted of 50 items and were randomized, and ear order was counterbalanced.

RESULTS

Speech Recognition Thresholds

SRT data were collected for each of three conditions (monaural right, monaural left, and binaural). Table 3 shows these data, along with the best monaural (mean) SRTs for each group. Repeated-measures analyses of variance (ANOVAs), combined with post hoc (Tukey's HSD) analyses, revealed two major, but not unexpected, findings in these data: (1) for all groups, the binaural SRTs were significantly ($p \leq .041$) better than both monaural SRTs, indicating a binaural advantage with this test; and (2) mean SRTs differed ($p \leq .034$) among all four subject groups, which agrees with the pure-tone threshold data. Also, the binaural SRTs were significantly ($p \leq$

Table 3 Means, SDs, and Ranges of Speech Recognition Thresholds for Each Condition by Group

Group	*Condition for SRT*	*Mean (in dB HL)*	*SD*	*Minimum (in dB HL)*	*Maximum (in dB HL)*	*Range*
YN	Right ear	6.67	2.87	2	12	10
	Left ear	4.83	2.76	0	10	10
	Binaural	3.00	2.49	−2	6	8
	Best ear	4.50	2.28	0	8	8
ON	Right ear	22.33	5.84	14	32	18
	Left ear	22.67	6.05	16	30	14
	Binaural	18.33	5.90	12	28	16
	Best ear	21.50	5.66	14	30	16
OHI	Right ear	31.75	7.53	16	42	26
	Left ear	31.75	7.86	14	42	28
	Binaural	27.92	6.47	12	36	24
	Best ear	29.92	7.29	14	42	28
OA	Right ear	41.08	13.63	25	66	41
	Left ear	43.58	13.04	28	66	38
	Binaural	36.75	13.71	22	64	42
	Best ear	40.75	13.39	25	66	41

SRT = speech recognition threshold, YN = young normal, ON = older normal, OHI = older hearing impaired, OA = older aided.

.012) better than the best monaural SRTs for all groups except the OHI group (p = .104).

Word Recognition Scores

The individual WRSs for each subject in each of the three conditions (monaural right, monaural left, and binaural) were measured. Mean WRSs, standard deviations, and ranges for each group for the three listening conditions, as well as the best monaural scores, are presented in Table 4. A 4 × 3 repeated-measures ANOVA was used to evaluate, statistically, differences among the three conditions for each of the experimental groups. Significant main effects were found for both condition ($F [2, 43] = 8.89$, $p = .001$) and group ($F [3, 44] = 12.18$, $p < .001$). A significant ($F [6, 86] = 2.375$, $p = .036$) condition by group interaction was also found. For condition, post hoc analysis using Tukey HSD tests found significant differences between the right (mean = 83.71%; range = 34%–98%) and left (mean = 79.54%; range = 24%–96%) monaural WRSs ($p < .002$) and the left (mean = 79.54%; range = 24%–96%) monaural and binaural (mean = 84.83%; range = 52%–100%) WRSs ($p < .003$). There was no significant difference between the right monaural and binaural WRSs ($p = 1.000$).

Table 4 Means, SDs, and Ranges of Word Recognition Scores for Each Condition by Group

Group	*Condition for WRS*	*Mean (%)*	*SD*	*Minimum (%)*	*Maximum (%)*	*Range (%)*
YN	Right ear	95.00	2.17	92	98	6
	Left ear	93.33	3.11	88	96	8
	Binaural	95.50	3.53	90	100	10
	Best ear	95.83	1.59	94	98	4
ON	Right ear	87.00	7.51	74	96	22
	Left ear	86.67	8.15	70	96	26
	Binaural	85.67	9.75	64	96	32
	Best ear	89.33	7.20	74	96	22
OHI	Right ear	76.50	16.07	34	98	64
	Left ear	70.50	19.26	24	92	68
	Binaural	81.50	11.70	52	92	40
	Best ear	77.17	16.57	34	98	64
OA	Right ear	76.33	7.57	66	88	22
	Left ear	67.67	14.39	40	88	48
	Binaural	76.67	12.04	54	94	40
	Best ear	77.33	7.74	66	88	22

WRS = word recognition score, YN = young normal, ON = older normal, OHI = older hearing impaired, OA = older aided.

Table 5 Means, SDs, and Ranges of Word Recognition Scores by Group

Group	*Mean (%)*	*SD*	*Minimum WRS (%)*	*Maximum WRS (%)*	*Range (%)*
YN	94.61	3.05	88	100	12
ON	86.44	8.30	64	96	32
OHI	76.17	16.17	24	98	74
OA	73.56	12.11	40	94	54

WRS = word recognition score, YN = young normal, ON = older normal, OHI = older hearing impaired, OA = older aided.

Table 5 contains the means, standard deviations, and ranges of the WRSs of the four groups. The YN group (mean = 94.61%; range = 88%–100%) was found to have significantly ($p \leq .01$) better WRSs than both the OHI (mean = 76.17%; range = 24%–98%; $p < .001$) and OA (mean = 73.56%; range = 40%–94%; $p < .001$) groups but not the ON (mean = 86.44%; range = 64%–96%; $p = .176$) group. The ON group also had better ($p = .011$) WRSs than the OA group. The significant group by condition interaction was due to the finding that, for groups OHI and OA but not YN and ON, the left ear WRSs were significantly ($p \leq .05$) poorer than both the right ear and binaural scores, but the right ear scores did not differ ($p > .05$) from the binaural scores.

Each individual's best monaural WRS was compared to his/her binaural WRS to determine which listening condition, if any, allowed for optimum word recognition performance. Figure 2 shows the number of subjects who performed best in each listening condition. For three of the four groups (YN, OHI, OA), the majority (56%) of subjects performed better in the binaural condition. However, in the ON group, the majority (58%) of the subjects performed better in a monaural condition. In the YN and ON groups, some subjects (17% in YN; 25% in ON) showed no differences between best monaural and the binaural WRSs. This finding was not present for the OHI and OA groups. All subjects in the OHI and OA groups showed either a monaural or binaural advantage. Figure 3 shows the individual difference scores for all 48 subjects. Examination of this figure indicates that, if the range of performance exhibited by the YN group defines expectation based on chance, then a total of seven subjects in the older groups showed binaural interference. At the same time, however, a total of 10 of these subjects showed evidence of binaural advantage. The data from individual subjects were formally analyzed by using the tables of confidence levels for determining the probability of differences between WRSs (Raffin and Thornton, 1980). The degree of these differences reached significance ($p < .05$) in three subjects. Table 6 summarizes the results for these three subjects. There were no subjects from the YN group who showed significant differences between the best monaural and binaural WRSs.

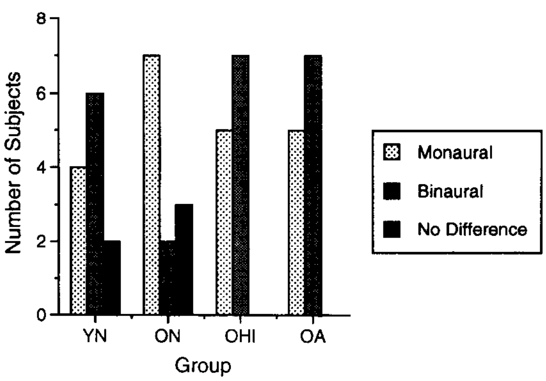

Figure 2 Number of subjects by group (YN = young normal, ON = older normal, OHI = older hearing impaired, OA = older aided) whose best word recognition score was in the monaural or the binaural listening condition.

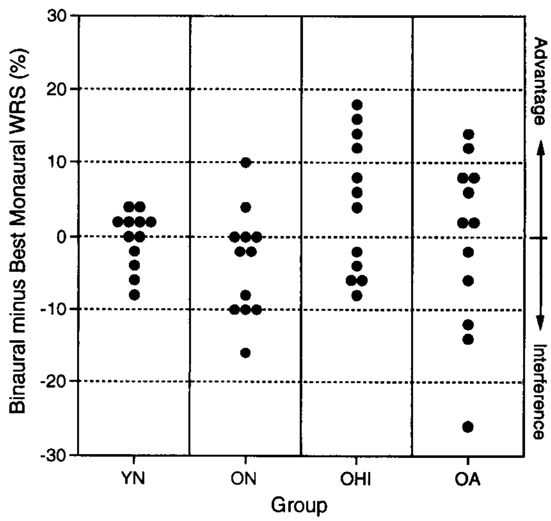

Figure 3 Scatter plot of differences between best monaural and binaural word recognition scores (WRSs) by group. A positive number indicates a binaural advantage and a negative number represents a monaural advantage. YN = young normal, ON = older normal, OHI = older hearing impaired, OA = older aided.

DISCUSSION

Statistical probability ($p < .05$) would dictate that, by chance, 2 of the 48 subjects in this study would demonstrate significant differences between their best monaural and binaural

Table 6 Summary of Results from Three Subjects Showing Significant Differences between the Best Monaural and Binaural Word Recognition Scores

Subject	Gender/Age	Group	HFPTA Right	HFPTA Left	WRS Right (%)	WRS Left (%)	WRS Binaural (%)	Confidence Level
JE	F/73	ON	36.7	28.3	80	92	76	.029
GF	M/64	OHI	43.3	48.3	74	70	90	.037
AM	M/85	OA	75.0	73.3	80	66	54	.007

HFPTA = high-frequency pure-tone average, WRS = word recognition score, ON = older normal, OHI = older hearing impaired, OA = older aided.

WRSs. Three subjects in the present study showed this effect. Two of these subjects showed evidence of binaural interference, whereas the third subject showed a significant ($p < .05$) binaural advantage.

Of the two subjects who exhibited binaural interference, one was in the OA group and the other was in the ON group. Subject AM from the OA group was an 85-year-old male who is aided binaurally. He had monaural WRSs of 80 percent for the right ear and 66 percent for the left ear and a binaural WRS of 54 percent. The difference of 26 percent between the best monaural and the binaural score was significant ($p = .007$; Raffin and Thornton, 1980).

Of particular interest is subject JE, a 73-year-old female from the ON group who had a difference of 16 percent between her best monaural WRS of 92 percent and binaural WRS of 76 percent. This difference was also significant ($p = .029$) based on the Raffin and Thornton (1980) tables of confidence levels. The presence of binaural interference in an ON adult is interesting, and one must question if this phenomenon may occur because of aging factors that are independent of factors such as noise exposure or diseases that cause impaired peripheral sensitivity. Certainly, binaural interference in this instance did not arise from a prolonged auditory deprivation due to an asymmetry in hearing levels. Based on the results of the present study, it may be possible that 8 to 10 percent of elderly individuals may exhibit binaural interference, regardless of hearing status. The findings with JE also suggest that binaural interference cannot be predicted on the basis of significant differences between individual ear WRSs. Her monaural word recognition performance was 80 percent and 92 percent for the right and left ears, respectively. This 12 percent difference is not statistically significant ($p > .05$).

The third subject, GF, a 64-year-old male, had WRSs of 74, 70, and 90 percent for the monaural right, monaural left, and binaural listening conditions, respectively. The 16 percent advantage in the binaural condition was significant ($p < .05$; Raffin and Thornton, 1980), and, again, this advantage could not be predicted from comparison of individual ear WRSs alone.

Although the present research findings, combined with those of earlier research reports (Arkebauer et al, 1971; Jerger et al, 1993; Chmiel et al, 1997), suggest that the prevalence of binaural interference in the elderly population is close to that expected by statistical chance, it may still be, although rare, a real clinical entity that deserves the attention of the audiology community. It is to the benefit of the clinician and the patient to determine the existence of binaural interference prior to any hearing aid fitting. The time investment in conducting binaural WRSs in addition to the routine monaural test protocol is minimal. In instances of binaural interference of any magnitude, an extended trial period and a careful monitoring program may be needed to facilitate adjustment to amplification and prevent hearing aid rejection.

It is not known if binaural interference, which has been estimated to include as many as 10 percent of elderly hearing aid users, is a factor in the decision to return hearing instruments. Further research is needed to examine this issue and the prevalence of binaural interference in normal-hearing adults in any decade of life. A weakness of the present study was that it was not possible to perform repeated testing of subjects to determine if any evidence of binaural interference was real or due to chance test–retest variability. Future studies must include this important control condition.

Finally, one additional interesting finding of the present study needs to be discussed inasmuch as it relates to recent findings by Jerger et al (1995) of age-related breakdowns in the interhemispheric transfer of information. The two older groups (OHI, OA) with hearing loss exhibited significantly poorer WRSs for the left ear than for either the right ear or the binaural listening condition. The ON group, which had better hearing sensitivity, did not exhibit this right ear advantage. The implications are that elderly persons with hearing loss may represent a physiologically older subset of the aging population than do their peers who have more normal peripheral sensitivity. Such persons, in addition to having cochlear dysfunction, may also exhibit degraded transmission of speech information across the corpus callosum to the language-dominant left hemisphere (Chmiel et al, 1997).

REFERENCES

Arkebauer HJ, Mencher GT, McCall C. (1971). Modification of speech discrimination in patients with binaural asymmetrical hearing loss. *J Speech Hear Disord* 36:208–212.

American Speech-Language-Hearing Association. (1988). Guidelines for determining threshold level for speech. *ASHA* 30:85–89.

American Speech-Language-Hearing Association. (1990). Guidelines for screening for hearing impairments and middle ear disorders. *ASHA* 32(Suppl 2):17–24.

Chmiel R, Jerger J, Murphy E, Pirozzolo F, Tooley-Young C. (1997). Unsuccessful use of binaural amplification by an elderly person. *J Am Acad Audiol* 8:1–10.

Folstein MF, Folstein SE, McHugh PR. (1975). "Mini-Mental State". A practical method for grading the cognitive state of patients for the clinician. *J Psychiatr Res* 12:189–198.

Hurley RM. (1999). Onset of auditory deprivation. *J Am Acad Audiol* 10:529–534.

Jerger J. (1994). The phenomenon of binaural interference. *Hear Instr* 45(1):29.

Jerger J, Jordan C. (1992). Age increases asymmetry on a cued-listening task. *Ear Hear* 13:272–277.

Jerger J, Silman S, Lew H, Chmiel R. (1993). Case studies in binaural interference: converging evidence from behavioral and electrophysiologic measures. *J Am Acad Audiol* 4:122–131.

Jerger J, Alford B, Lew H, Rivera V, Chmiel R. (1995). Dichotic listening, event-related potentials, and interhemispheric transfer in the elderly. *Ear Hear* 16:482–498.

Raffin MJM, Thornton AR. (1980). Confidence levels for differences between speech-discrimination scores. A research note. *J Speech Hear Res* 23:5–18.