Binaural Speech Recognition and the Stenger Effect

Sue A. Karsten
Christopher W. Turner
University of Iowa
Iowa City, IA

The present investigation examined the effects of systematically altering the balance between speech presentation levels to the 2 ears of 12 listeners with bilateral asymmetrical sensorineural hearing impairments. Speech-recognition scores for /VCV/ speech stimuli were obtained from each participant in quiet for 9 conditions ranging from monaural poorer ear only to monaural better ear only, with 7 intermediate conditions in which the sound balance between ears was varied in 5-dB steps. High-pass spectral shaping was provided to the poorer ear, and unshaped amplification was provided to the better ear. The results suggested that, as a group, varying the sound level in the better ear within −20 to +10 dB of the centered position did not significantly change the speech recognition for these participants. No evidence of binaural interference was obtained. Findings also showed that in binaural listening situations, the Stenger effect has little influence upon speech-recognition scores. Even when the listeners were unaware of speech being presented to the better ear, their speech-recognition score reflected the better ear's abilities.

KEY WORDS: asymmetrical, binaural, binaural interference, speech recognition, Stenger effect

The general acceptance by clinicians that binaural hearing-aid fittings are preferable to monaural, even for those individuals with asymmetrical hearing losses, is supported by the well-documented auditory advantages provided by binaural hearing. When compared to monaural hearing, binaural advantages include more efficient localization of sounds, improved speech intelligibility in the presence of background noise, due in part to a squelch effect, which suppresses background noises, binaural summation, and ease of listening (Koehnke & Besing, 1997). Although the premise that "two ears are better than one" appears to hold truth, there is research that suggests when some individuals with asymmetrical hearing losses are fitted with two hearing aids, their binaural performance is worse than their better ear alone. This has been termed "binaural interference" or a "principle of degradation" (Harris, 1965). It is not clear from the existing literature just when amplifying the speech presented to the poorer ear of patients with asymmetrical hearing losses might actually serve to decrease their binaural speech-recognition performance. It is also not clear how changing the balance between the sound levels directed to each ear will affect speech recognition.

A number of factors may have a strong influence on whether two ears are really better than one when it comes to amplification for the patient with an asymmetrical hearing loss. The first factor to be reviewed will be the status of the poorer ear. If that ear has little speech-recognition

1092-4388/00/4304-0926

ability alone, then amplifying it may not add to the patient's overall score. Furthermore, if the poorer ear actually provides "mis-information" of the speech signal as a result of cochlear damage, then amplifying that ear could even decrease the binaural performance. Another important factor to consider is the relative "balance" between the two ears in terms of the presentation levels of speech. It may be the case that if the poorer ear is amplified too much relative to the better ear, the patient will become unaware of, and unable to use, the information provided by the better ear. Both of these factors, the ability of the poorer ear to perceive speech under monaural conditions and the relative levels of speech presented to the poorer versus the better ear, have the potential to affect a patient's performance with binaural amplification (and even monaural amplification, if the better ear is normal and unamplified).

Arkebauer, McCall, and Mencher (1971) conducted a study that suggested the presence of binaural interference among 10 participants with asymmetrical hearing loss. Speech-recognition scores were obtained from the participants for each ear in isolation under headphones, in a binaural sound-field condition and in a poorer-ear-occluded sound-field condition. The results of this study revealed that in 9 of the 10 cases, the speech-recognition scores were higher for the better ear alone than in the binaural condition. These reduced scores suggested the occurrence of binaural interference. In addition, 8 of the 10 cases showed an improvement in speech recognition when the poorer ear was occluded. However, their results may be misleading due to uncontrolled differences in speech audibility when results between headphone and sound-field conditions were compared. Jerger, Silman, Lew, and Chmiel (1993) provided evidence of binaural interference in a review of four case reports. After being fit with behind-the-ear hearing aids, one patient displayed speech-recognition scores of 64% for monaural left-ear aided, 0% for monaural right-ear aided, and 22% for the binaurally aided condition. These results also suggested that the poor ear input had an adverse effect on the aided binaural performance. The investigators provided information for other cases where the hearing losses were essentially symmetrical but the speech-recognition scores were asymmetrical. Again, the results showed that the binaural performance was worse than the better ear alone.

McCullough (1986) investigated the relationship between interaural differences in speech recognition in noise and binaural advantage. The study used 5 hearing-impaired participants who displayed actual speech-recognition differences between ears and 18 normal-hearing participants with simulated interaural speech-recognition differences. The interaural speech-recognition differences in the normal-hearing participants were accomplished by spectral degradation of the speech stimuli. Participants listened to the stimuli under headphones, and signal-to-noise ratios for 50%-correct performance were measured for monaural and binaural listening conditions. Binaural advantage was determined by calculating the signal-to-noise ratio differences between the monaural and binaural conditions. For the normal-hearing participants with simulated interaural speech-recognition differences, the results indicated that binaural advantage was greatest when the stimulus was not degraded, and decreased as the amount of spectral degradation was increased. The results, which are of interest to the present investigation, showed that the binaural performance at times was worse than the monaural. However, the results from the hearing-impaired listeners were very diverse and inconsistent on this point. Hood and Prasher (1990) also investigated the effect of simulated bilateral cochlear distortion in listeners with normal hearing. In one test, phonetically balanced words were presented under a high-pitch distortion (HPD) monaural condition, a low-pitch distortion (LPD) monaural condition, and a binaural condition with LPD to one ear and HPD to the other ear. Although the differences were not statistically significant, the speech-recognition scores for binaural stimulation were less than the best monaural score.

The prevalence of this "binaural interference" phenomenon is essentially unknown. Jerger et al. (1993) reported data collected from 37 patients evaluated for hearing aids at their audiology service, showing that 3 of these patients performed better in the monaural condition (best ear) than in the binaural condition. It is not clear if this effect exists in a significant proportion of patients with asymmetrical hearing losses and under what conditions it might exhibit itself.

One factor that would appear to be important in eliciting the effect would be the presentation levels of speech to the two ears. Durlach, Thompson, and Colburn (1981) described a number of methods used in investigations to balance the stimulus amplitude to both ears: equal SPLs to both ears, equal SLs to both ears, equal loudness to both ears via alternate presentation of sounds, and centering of the sound image with a simultaneous presentation of sounds. Durlach et al. (1981) suggested that the values obtained from these four different methods are essentially the same in listeners with normal hearing. However, for hearing-impaired listeners, the values obtained are often significantly different. Since binaural hearing-aid fittings are often balanced by "centering," this method was used in our investigation to determine a baseline presentation level.

One might also ask if presenting speech to one ear at a higher level than the other might cause the listener to "ignore" information to the softer ear. The Stenger test (Stenger, 1907) has been used over the years to identify pseudohypacusis in patients claiming a hearing impairment in one ear. The Pure-Tone Stenger Test is based on the fact that whenever both ears are simultaneously presented with tones of equal frequency but differing intensities, an individual with normal hearing or symmetrical bilateral hearing loss will perceive sound only in the ear in which the louder tone was presented. In cases of malingering, when the tone is approximately 10 dB greater in the claimed poorer ear than in the better ear, the patient will be unaware that he is still receiving a stimulus to the better ear and only hear the tone in the poorer ear. The Modified or Speech Stenger Test (Taylor, 1949) uses speech as the auditory signal instead of pure tones, but is otherwise conducted and interpreted in the same manner as the Pure-Tone Stenger. In the present investigation, we were interested in the effects of altering the sound level balance positions in patients with bilateral asymmetrical hearing impairments, and whether input from the poorer ear, if presented at sound levels that produce a Stenger effect, could have an adverse effect on binaural hearing performance.

Although numerous studies have shown an advantage of binaural hearing aids over monaural better-ear hearing-aid use (Harris, 1965; Harris & Myers, 1971; Hawkins & Yacullo, 1984; Libby, 1980; Markides, 1977), these results included the advantages offered by two ears due to localization of spatially separate noise and speech. The question remains, however, whether speech being made audible to the poorer ear can detract from a person's speech-recognition ability. Thus, one aspect of this investigation was to determine if binaural interference could be found among patients with asymmetrical hearing loss using an identical sound-delivery system across conditions without background noise, and for the present time disregarding the confounding effects of localization or masking level differences. Another question addressed is whether the potential advantages or disadvantages of two ears depend upon the balance position between the ears. This investigation was designed to determine:

1. Does "centering" provide the most advantage for speech recognition in patients with bilateral asymmetrical hearing loss, or is another balance position better?

2. Is it beneficial or detrimental to provide speech to the poorer ear of some patients with asymmetrical hearing loss?

Method

Participants

Twelve listeners (2 women and 10 men, ages 39–79, mean age = 61.2 years) with bilateral asymmetrical sensorineural hearing loss participated in the study. Individual audiometric data are described in Table 1, and the selection criteria were as follows: poorer than 20 dB HL from 1000 to 4000 Hz in each ear, 20 to 60 dB interaural difference at any or all frequencies from 500 to 4000 Hz, and/or >15% interaural difference for clinical word-recognition testing, with no evidence of retrocochlear pathology or conductive hearing loss. The listeners were paid for participating in this study.

Speech Materials

The speech stimuli consisted of 16 /VCV/ syllables, using the vowel /a/ and one of 16 consonants /b, p, f, v, s, z, m, n, k, g, t, d, ʃ, ʒ, θ, ð/. Because we wanted to more realistically depict the wide frequency range and speaking style of speakers from which listeners with hearing impairments need to discriminate speech in everyday situations, the syllables were spoken by four talkers (two men and two women) for a total of 64 items per run. Participants heard each of the 64 tokens once per run. The presentation order of the /VCV/ syllables and talkers were randomized in each experimental run, and the speech stimuli were recorded and played digitally using a DigiDesign D/A system and stored on a Macintosh 9500 computer.

Stimulus Presentation

For the purpose of improving audibility of the speech syllables for the listeners with bilateral asymmetrical hearing impairments, a single standard high-pass spectral shaping was used to provide approximately 15 to 25 dB of gain across 800 to 4000 Hz to the poorer ear of all the participants. Unshaped amplification was provided to the better ear. The speech stimuli were presented via ER-3A insert earphones calibrated for phase and positioned so the outside of the cushion was flush with the opening to the ear canal.

The beginning of the experiment involved finding the participant's centered listening position. The most comfortable level within the audible range for the poorer ear was determined while no sound was presented to the better ear. The initial presentation level was determined as follows: After plotting the listener's pure-tone thresholds, an audible speech level was determined when the long-term speech spectrum of the stimuli (expressed in 1/3-octave band levels), including the spectral shaping for the poorer ear, was above the listener's pure-tone thresholds for the major part of the speech range (500–3000 Hz). Most comfortable level was then determined by asking the listener to rate the /VCV/ syllables presented in 2-dB steps as too loud, high end of comfortable, comfortable, or too soft. The goal was to maximize audibility of the speech signal while avoiding discomfort for the listener. The comfortable sound level

Table 1. Age (years), hearing thresholds (dB HL), and clinically determined word-recognition scores for 12 hearing-impaired participants. Poorer ear is shown in parentheses for each participant. (*Information not available.)

Participant	Age	Ear	Frequency (Hz) 250	500	1000	2000	4000	8000	Clinical word recognition (%)	Materials
1	72	R	40	30	35	70	70	75	92	Maryland CNC
		(L)	30	25	50	95	100	105	38	
2	55	(R)	80	70	80	75	65	70	24	Maryland CNC
		L	20	30	25	25	55	50	94	
3	59	R	25	30	25	20	45	45	96	Maryland CNC
		(L)	70	70	65	60	65	60	48	
4	77	R	20	20	30	30	55	65	84	Maryland CNC
		(L)	65	70	75	75	75	85	20	
5	39	(R)	35	30	90	85	85	75	56	Maryland CNC
		L	25	25	25	30	55	60	96	
6	79	R	40	40	45	60	75	105	96	Maryland CNC
		(L)	65	70	75	85	95	85	52	
7	51	(R)	45	55	70	90	110	110	0	SPIN
		L	40	35	40	70	85	70	72	
8	52	(R)	55	60	65	65	65	85	60	CID W-22
		L	40	40	40	45	55	75	88	
9	56	(R)	85	90	90	85	70	95	20	Maryland CNC
		L	50	55	60	65	65	50	96	
10	58	(R)	30	50	55	60	75	80	*	
		L	5	15	25	45	65	70	*	
11	68	(R)	20	20	45	75	80	70	24	SPIN
		L	10	10	30	50	70	65	44	
12	68	(R)	*	55	60	70	95	*	46	Maryland CNC
		L	*	55	55	65	95	*	72	

in the poorer ear was then decreased by 3–5 dB to compensate for binaural summation of loudness when the better ear was added. Pilot work indicated that without such a correction, binaural stimulation was too loud for the participants. The sound level in the poorer ear was then held constant while the same speech signal (not spectrally shaped) was presented to the better ear at various levels. The participant was instructed to listen to two or three syllables at each level to the better ear and then report whether the sound was perceived to be centered, shifted to the right ear, or shifted to the left ear. From these responses, a centered baseline position was determined.

The second part of the experiment measured speech recognition. Participants responded to the speech stimuli by pressing labeled buttons on a response panel corresponding to the various consonants in a 16-alternative forced-choice procedure. Participants were given specific training as to which speech sounds corresponded to each button along with two practice runs with feedback. Recognition in percent correct was measured for each participant at each of the conditions listed in Table 2. The presentation level for the poorer ear was the same for each condition (except better-ear monaural) while the better ear presentation level was varied in 5-dB steps

Table 2. Test conditions. The presentation level for the poorer ear was held constant for each condition (except better ear monaural), and the better ear presentation level was varied in 5-dB steps about the centered position.

Condition	Better ear (dB re: centered position)	Poor ear
1	Signal Off	Fixed at centered level
2	−20	Fixed at centered level
3	−15	Fixed at centered level
4	−10	Fixed at centered level
5	−5	Fixed at centered level
6	0 dB, centered	Centered
7	5	Fixed at centered level
8	10	Fixed at centered level
9	0	Signal Off

about the centered position. Monaural poorer-ear scores were obtained with and without masking noise presented to the better ear to determine if the scores changed due to a low-level contribution from the better ear via crossover. For 3 of the participants, crossover did occur, so the monaural poorer-ear scores were obtained with masking. Three runs (64 items per run) without feedback were then obtained for each of the nine conditions (presented in randomized order). The final speech-recognition score for each condition was determined by averaging the three runs. After each condition, participants were asked whether the sound was centered or shifted to the right or left ear in the preliminary centering portion of the experiment, as well as during the actual experiment.

Results

Speech-recognition scores for seven of the test conditions (–20, –15, –10, –5, 0, +5, +10 dB re: centered position) are plotted in Figure 1. To interpret the graph, the numbers across the abscissa indicate the better ear level (in dB) relative to the centered position. A one-factor, repeated-measure analysis of variance (ANOVA) performed on the arcsine-transformed data (Studebaker, 1985) indicated that there was no effect of level [$F(6, 72) = 1.04$, $p = .408$]. This suggests that, as a group, varying the sound level in the better ear across a 30-dB range did not significantly change the speech recognition for these patients, in spite of the fact that the speech-recognition abilities of the two ears were different.

The latter point is illustrated in the individual results for Participants 2 and 6, shown in Figure 2. The monaural endpoints for both patients indicate a significant interaural speech recognition difference. However, the scores of the two-ear test conditions show generally flat functions with scores similar to that of the better-ear monaural condition. Table 3 shows the speech-recognition scores for the monaural better-ear and the monaural poorer-ear conditions.

Since performance variability across participants is an inherent property due to the heterogeneous nature of the hearing-impaired population, it may be worthwhile to examine each listener's results individually. To address the first research question of whether centering provides the most advantage for speech recognition in patients with bilateral asymmetrical hearing losses, the individual data were analyzed using 95% confidence intervals based on the principles of the binomial distribution for speech recognition (Thornton & Raffin, 1978).

Figure 1. Speech recognition scores in percent correct as a function of better ear level for seven of the test conditions. The thick solid line with filled squares represents the group mean data, and the thin lines represent individual data. The numbers across the abscissa indicate the better ear level (in dB) relative to the centered position. Zero on the abscissa represents the centered position. Participant numbers in Figure 1 legend correspond to the participant numbers in Table 1.

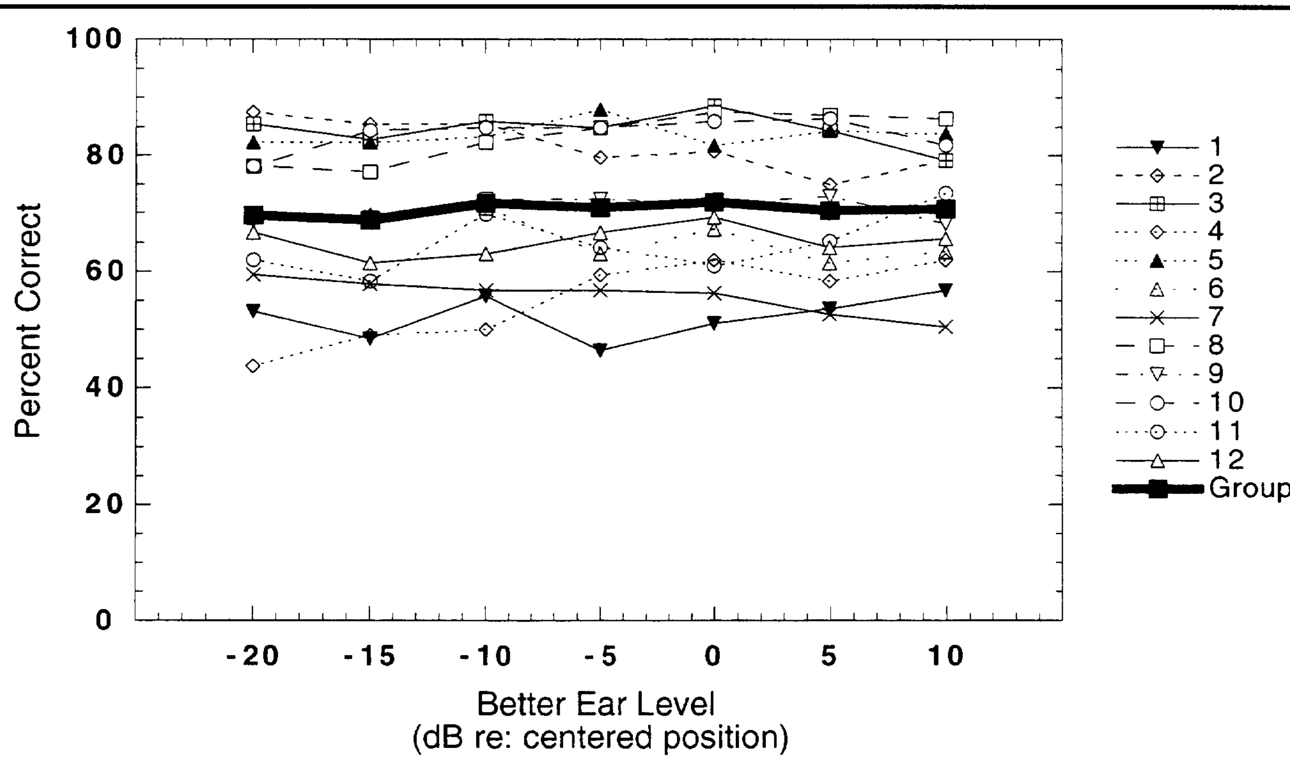
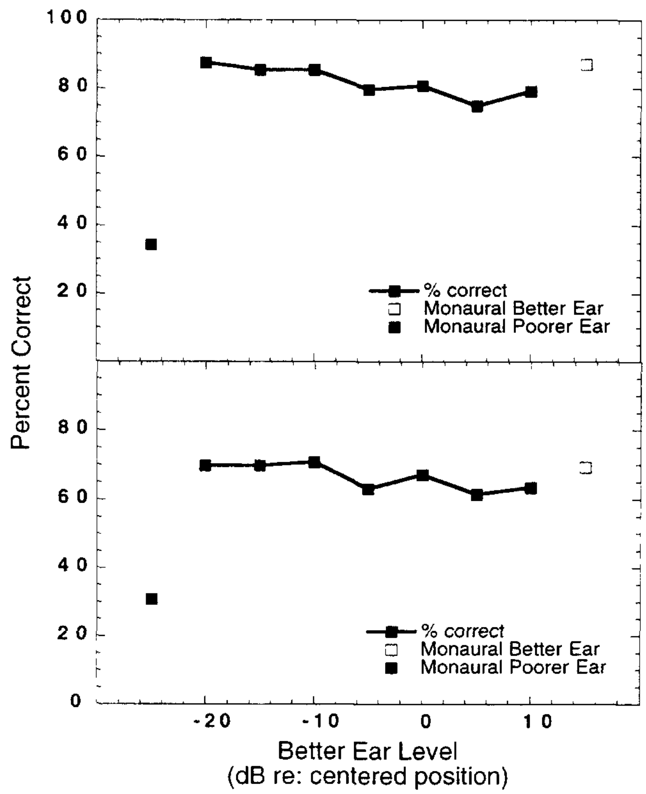


Figure 2. Speech recognition scores in percent correct as a function of better ear level for all of the test conditions for Participant 2 (upper) and Participant 6 (lower). The thick solid line with filled squares depicts scores for the seven binaural conditions; the filled single square depicts the monaural poorer ear score; and the open single square depicts the monaural better ear score. Note the significant interaural speech recognition difference in the monaural scores.



With one exception, there was no statistically significant difference between the speech-recognition scores of the centered condition versus the best condition for each individual. When the centered condition was compared to the worst condition (excluding the poorer ear monaural) for each individual, it was found that there were generally no statistically significant differences. The few exceptions (3 out of 12) were in the conditions that were at least 10 dB from centered. While there were several (7 out of 12) statistically significant differences between the best condition and the worst condition, these differences were either small (in percent correct) or in conditions that were at least 10 dB from centered. In general, the individual data revealed a relatively constant percent-correct score across the test conditions, which suggests that varying the sound level in the better ear within –20 to +10 dB of the centered position does not significantly change the speech recognition for these patients. However, it should be noted that several participants reported a preference for listening to the centered condition over the others indicating that centering enhances "ease of listening" for some patients.

Table 3. Speech-recognition scores in percent correct for monaural-poorer-ear and monaural-better-ear conditions for all participants.

Participant	Monaural poorer ear	Monaural better ear
1	37.49	52.61
2	34.38	86.98
3	70.31	83.85
4	6.77	60 94
5	58 33	81.25
6	30.73	69.27
7	47.92	51.85
8	67.71	84.91
9	14.06	70.31
10	65.11	85.94
11	67.71	60.94
12	54.69	61.98

To address the second research question of whether it is beneficial to give speech to the poorer ear of some patients with asymmetrical hearing loss, the monaural better-ear condition was compared to the best condition for each individual. With one exception, it was found that adding the poorer ear to the testing situation (best condition) showed no statistically significant (>95% confidence intervals) improvement or detriment over the better ear alone. Recall, that the present data were collected across conditions without background noise. Numerous studies have shown an advantage of binaural hearing aids over monaural better-ear hearing-aid use in conditions which included the advantages offered by two ears due to localization of spatially separate noise and speech. The present study did not investigate this factor.

This study also determined if binaural interference could be found among our participants using an identical sound-delivery system and conditions without background noise. The best binaural condition and the centered condition were each compared to the monaural better-ear condition to determine if binaural performance was ever found to be poorer than the better ear alone. Based on 95% confidence intervals, no evidence of significant binaural interference was found among the 12 participants in this study.

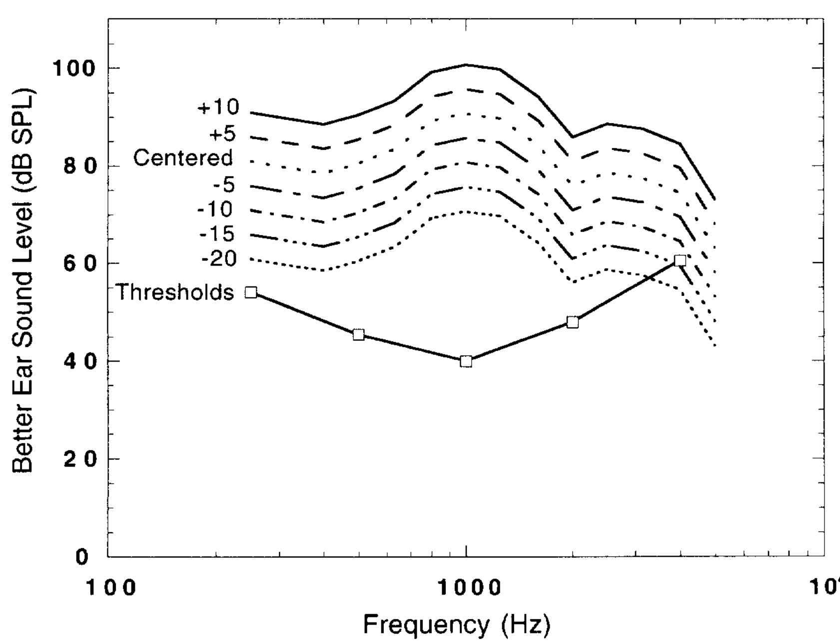
Discussion

As shown in Figures 1 and 2, varying the sound level in the better ear within –20 to +10 dB of the centered position did not significantly alter the speech-recognition scores for these patients. Firstly, one might wonder why we did not see a decrease in performance for the –20-, –15-, –10-, and –5-dB conditions. As illustrated in Figure 3 (Participant 8), when the better ear was balanced to the poorer ear at the centered baseline condition, the sound level presented to the better ear was well above the detection thresholds. In this figure, the better-ear pure-tone thresholds are plotted along with the 1/3-octave-band speech levels for the various experimental conditions. Reducing the sound level in the better ear as much as 20 dB relative to the centered position did not bring the speech level below threshold across most of the frequencies; thus, the listeners did not experience a significant decrease in audibility except for the condition in which the better ear was completely attenuated. When such a patient adjusts the poorer ear level to a comfortable and audible speech presentation level, or if the poorer ear is fit with a hearing aid using one of the audibility-based fitting strategies, then a "centered" level for the better ear will usually be considerably suprathreshold.

One might also speculate why the contribution of the poorer ear in the binaural conditions did not result in an increase in the speech-recognition scores. Maybe this is not altogether surprising since the poorer ear may be viewed as just a poorer version of the better ear for the participants in this study, and therefore does not contribute any "new" speech cues.

The long-standing phenomenon known as the Stenger effect played an interesting role in this experiment. When the sound level was increased or decreased in the better ear as little as 5 dB from the centered position, most participants were then not aware that the speech stimuli were actually being presented to both ears. The sound lateralized to the ear in which the greater speech level was presented. Therefore, we expected that the Stenger effect might negatively influence binaural speech scores when the patient was only aware of speech being presented to the poorer ear. If a person is not aware of sound coming into one of his ears, is he or she able to use that information? Under these conditions, Participant 2 (see Figure 2) remarked during the experiment that he had not heard sounds so clearly in his poor ear for a long time. At the –5-, –10-, –15-, and –20-dB conditions, this listener perceived the speech-syllable stimuli only in the poor ear. However, we must conclude from the speech-recognition scores that he derived benefit from both ears. This demonstrates that just because a patient is unaware of the stimulus being presented to an ear does not mean that he is unable to use the information provided by that ear. All participants were tested at conditions where speech was lateralized to the poorer ear in several conditions yet their speech-recognition performance was unchanged.

Figure 3. Better ear sound level (dB SPL) as a function of frequency for Participant 8. The thick solid line with open squares depicts the listener's better ear thresholds. The presentation levels at the various conditions are shown by the solitary dashed and solid lines. Reducing the sound level in the better ear as much as 20 dB relative to the centered position did not bring the speech level below threshold across most of the frequencies.



Researchers have seen related results in experiments that demonstrated the precedence effect where listeners suppress the separate perception of echoes up to approximately 50 milliseconds. However, even though the listener is unaware of the sound event of the echo, the presence of suppressed echoes provides information on localization, room size as well as a contribution to sound quality (Wallach, Newman, & Rosenzweig, 1949). Schlauch, Clement, Ries, and DiGiovanni (1999) showed that an unperceived masker (due to Stenger effect) could still influence an intensity discrimination task. Thus, the lateralization and awareness of individual sounds in a binaural listening situation appear to be separate phenomena from the information transmitted by the sounds to the listener.

In review of the data collected in the present experiment from 12 participants with bilateral asymmetrical hearing impairments, we have shown that the Stenger effect has little influence upon speech recognition in a binaural situation. No evidence of binaural interference was obtained. In addition, although patients may prefer a "centered" or some other loudness balance between the ears, in terms of speech-recognition scores, choice of this balance point is not critical over an approximately 30 dB range when speech-recognition performance is the measure of interest.

Acknowledgments

This research was supported by NIDCD Grant 2 R01 DC00377-12 and The University of Iowa, Department of Speech Pathology and Audiology Sherman Scholar Honors Program. The authors would like to thank Bom Jun Kwon and Maureen Mehr for their helpful comments on an earlier draft of this article and the Department of Veterans Affairs Medical Center in Iowa City for their assistance in recruiting participants. This research was conducted as an Undergraduate Honors Thesis by the first author.

References

Arkebauer, H. J., McCall, C., & Mencher, G. T. (1971). Modification of speech discrimination in patients with binaural asymmetrical hearing loss. *Journal of Speech and Hearing Disorders, 36,* 208–212.

Durlach, N. I., Thompson, C. L., & Colburn, H. S. (1981). Binaural interaction in impaired listeners: A review of past research. *Audiology, 20,* 181–211.

Harris, J. D. (1965). Monaural and binaural speech intelligibility and the stereophonic effect based upon temporal cues. *Laryngoscope, 75,* 428–446.

Harris, J., & Myers, C. (1971). Binaural improvement in normal and defective ears in a background of other voices. *US Naval Submarine Medical Center* (Rep. 677), 1–5.

Hawkins, D. B., & Yacullo, W. S. (1984). Signal-to-noise ratio advantage of binaural hearing aids and directional microphones under different levels of reverberation. *Journal of Speech and Hearing Disorders, 49,* 278–286.

Hood, J. D., & Prasher, D. K. (1990). Effect of simulated bilateral cochlear distortion on speech discrimination in normal subjects. *Scandinavian Audiology, 19,* 37–41.

Jerger, J., Silman, S., Lew, H. L., & Chmiel, R. (1993). Case studies in binaural interference: Converging evidence from behavioral and electrophysiologic measures. *Journal of the American Academy of Audiology, 4,* 122–131.

Koehnke, J., & Besing, J. (1997). Binaural performance in listeners with impaired hearing: Aided and unaided results. In R. H. Gilkey & T. R. Anderson (Eds.), *Binaural and spatial hearing in real and virtual environments* (pp. 725–751). Hillsdale, NJ: Erlbaum.

Libby, E. R. (1980). *Binaural hearing and amplification* (Vols. 1 & 2). Chicago: Zenetron.

Markides, A. (1977). *Binaural hearing aids.* New York: Academic Press.

McCullough, J. K. (1986). *Effects of interaural spectral differences on binaural word recognition in noise.* Unpublished doctoral dissertation, The University of Iowa, Iowa City, IA.

Schlauch, R. S., Clement, B. R., Ries, D. T., & DiGiovanni, J. J. (1999). Masker laterality and cueing in forward-masked intensity discrimination. *Journal of the Acoustical Society of America, 105*(2), 822–828.

Stenger, P. (1907). Simulation and dissimulation of ear diseases and their identification. *Deutsche Medizinsche Wochenschrift, 33,* 970–973.

Studebaker, G. A. (1985). A "rationalized" arcsine transform. *Journal of Speech and Hearing Research, 28,* 455–462.

Taylor, G. J. (1949). An experimental study of tests for the detection of auditory malingering. *Journal of Speech and Hearing Disorders, 14,* 119–130.

Thornton, A. R., & Raffin, M. J. M. (1978). Speech-discrimination scores modeled as a binomial variable. *Journal of Speech and Hearing Research, 21,* 507–518.

Wallach, H., Newman, E. B., & Rosenzweig, M. R. (1949). The precedence effect in sound localization. *The American Journal of Psychology, 62,* 315–336.

Received September 27, 1999

Accepted March 15, 2000

Contact author: Christopher W. Turner, Department of Speech Pathology and Audiology, 121B SHC, University of Iowa, Iowa City, IA 52242.
Email: christopher-turner@uiowa.edu