

BINAURAL INTERFERENCE

A Guide for Audiologists

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INTERFERENCE
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Preface by James Jerger

Many years ago, when I was teaching and researching at the Baylor College of Medicine in Houston, Texas, the public relations people at the medical school arranged for me to be interviewed by a reporter from a local Houston newspaper concerning the research projects we were currently conducting. In the course of the meeting, I mentioned that, while binaural aids were the standard of practice in our audiology clinic, we had identified a few elderly hearing aid users who preferred just one aided ear over both aided ears, and we were trying to understand the basis for this preference. The newspaper published a short piece on this at the bottom of the last column of one of the back pages of the paper. I forgot all about it until weeks later, when I received a short letter from a woman in North Carolina. She asked God to bless me for the item she found in her paper explaining our research. She said that she had been telling her audiologist for months that she didn't do well with both aids on in noisy places. She said that she did much better if she removed the aid from her left ear. Her audiologist had been insisting that she would get used to aids in both ears, but now she was sure that she had been right all along.

Apparently, one of the wire services picked up the item from the Houston paper and it spread nationwide. That single letter from a grateful monaural user convinced me that the apparent interaural conflict generated by binaural fittings in at least some elderly persons warranted serious consideration. I began the study of what came to be called "binaural interference," and have maintained an interest in the phenomenon for almost 50 years. In the 1980s, my good friends and colleagues Shlomo Silman, Carol Silverman, Michele Emmer, and their associates at the City University of New York began a series of studies on the phenomenon of auditory deprivation. It soon became apparent

that binaural interference and auditory deprivation were closely related. A research partnership developed between our two labs, resulting in a series of publications based on our joint interests. This book is the result of that long, fruitful, and continuing partnership.

We are indebted to many individuals for assistance with the preparation of this book, but especially Susan Jerger, whose support has been invaluable and unwavering. For their special contribution to our research into binaural interference at the Baylor College of Medicine, thanks to Henry Lew, Rose Chmiel, and Emily Murphy. Thanks, also, to Angie Singh and Valerie Johns, at Plural Publishing, for their much-appreciated support. Finally, we are indebted to Lina Reiss for her generous assistance with the editing of the sections on pitch matching, and for the important contributions that the research of her team at the Oregon Health Science University has made to the study of binaural interference.

—James Jerger, PhD

Preface by Carol A. Silverman

The first study on binaural interference, which resulted from a collaboration between Jim Jerger and his colleagues at Baylor College of Medicine and Shlomo Silman at the Brooklyn College Center for Auditory Research, published about 25 years ago, demonstrated that some individuals, particularly older individuals, perform more poorly with two hearing aids than with one and/or more poorly with binaural than monaural stimulation. Surprisingly, however, given the adverse impact of binaural interference on auditory function, and its occurrence in a significant subset of the population with hearing loss, research on binaural interference only recently has begun to flourish; and adaptation of audiologic clinical practice to identify, assess, and manage individuals with binaural interference has yet to become widespread.

My interest in binaural interference stems from my research with colleagues, particularly Shlomo Silman and Michele Emmer, on auditory deprivation associated with insufficient auditory stimulation, such as that observed in the unaided ear of monaurally fitted individuals with bilateral, symmetric, sensorineural hearing impairment. As will be shown in this text, auditory deprivation may represent one cause of binaural interference. My interest also stems from clinical observations of the many patients with bilateral, symmetric hearing loss who put one or both hearing aids away in a drawer, never to be used again. Undoubtedly, binaural interference furnishes the explanation for some of these cases. Such failure in the use of binaural amplification represents an unjustified expenditure to the individual and a cost to society because of inappropriate and ineffective health care.

We hope the reader will find the existing behavioral and electrophysiological evidence of binaural interference and its impact on auditory function to be compelling. It is our intent that this

text on binaural interference will accomplish the following two-fold goal:

1. Provide impetus for pursuing research to enhance (a) understanding of binaural interference in the unaided as well as aided conditions, including its psychoacoustic and physiologic bases; (b) its impact on auditory function; and (c) its management. As with many scientific phenomena, binaural interference is likely to be multifactorial and variable in clinical presentation.
2. Encourage audiologists to explore the possibility of binaural interference when patient complaints suggest this issue, and when performing audiological evaluations. Expanding the screening and diagnostic armamentarium to include procedures to identify and assess binaural interference will lead to the development and implementation of more efficacious management approaches that are targeted to the individual (e.g., eschewing the binaural amplification approach as a one-approach-fits-all with bilateral, symmetric sensorineural hearing loss).

Although we recognize that binaural interference can occur in individuals with cochlear implants, including those with bimodal fittings, the inclusion of binaural interference in individuals with cochlear implants is beyond the scope of this text.

Special appreciation is extended to Lina A.J. Reiss, PhD, who reviewed selected chapters, and to Susan W. Jerger, PhD, for her edits.

It has been a huge honor for me to have the experience of coauthoring a text with Jim Jerger. My heartfelt thanks go to my cherished husband, Shlomo Silman, PhD, for his unwavering and continuous support, guidance, and encouragement over the years, and to my dearly loved brother, Alan K Silverman, MD.

—Carol A. Silverman, PhD, MPH

1

A Brief History of Binaural Interference

VERN O. KNUDSEN

The first published suggestion that there might be such a thing as conflict between the two ears was apparently made in 1939 by Vern O. Knudsen (1893-1974), a world-renowned acoustical physicist at the University of California, Los Angeles. Knudsen is perhaps best known to audiologists as a cofounder of the Acoustical Society of America. Almost 80 years ago, in a paper entitled, "An Ear to the Future," published in the *Journal of the Acoustical Society of America*, Knudsen speculated about the future possibility of binaural hearing aids. He suggested that, although they were the undoubted wave of the future, their value might be limited in some hearing aid users. Knudsen had observed that, in cases of what we now call sensorineural hearing loss, a pitch discrepancy between ears sometimes seemed to generate an "inter-aural conflict" if both ears were amplified (Knudsen, 1939). Similar observations were reported in 1949 by Leland Watson and Thomas Tolan (1949). Their warnings were ignored for more than three decades.

In 1971, however, Arkebauer, Mencher, and McCall (1971) reported a curious finding. Previously Harford and Dodds (1966) had measured speech recognition in 29 persons with unilateral hearing loss under two conditions, (1) unaided and (2) aided by a Contralateral Routing of Signal (CROS) input fitted to the poorer ear. This, in effect, created binaural stimulation. In 14 cases, the binaural aided-by-CROS score was better than the unaided score, but in the remaining 15 cases, the unaided score still gave the better result. Reasoning that, in some cases, the impoverished signal provided by the CROS input might have actually interfered with the unaided signal, Arkebauer et al. set out to determine the effect of the input from the poorer ear on the better ear in 10 persons with asymmetric sensorineural loss. They tested speech recognition in the sound field under two conditions: first with the poorer ear open (binaural condition), then with the poorer ear occluded (monaural condition). Speech recognition was assessed

with W-22 word lists. Two groups of five individuals each were tested. In both groups, the hearing level on the poorer ear averaged about 60 dB, but in one group, the hearing level on the better ear averaged about 10 dB, whereas in the other group, the average level on the better ear was about 28 dB. The results seemed to confirm the hypothesis of interference from the poorer ear. In eight of the 10 participants, the speech score was better in the occluded (monaural) condition than in the unoccluded (binaural) condition. In the five listeners with only minimal loss in the good ear, the speech score improved by an average of 3.6 % when the poorer ear was occluded. In the five listeners with moderate loss in the better ear, the improvement when the poorer ear was occluded averaged 13.6%. Arkebauer et al. described the effect as, “*detrimental binaural interaction*” (p. 212). Perhaps because of the small number of participants, this study had little impact at the time it was published.

In 1984, the plot began to thicken. Shlomo Silman, Stanley Gelfand, and Carol Silverman reported the results of the analysis of W-22 scores over a 4- to 5-year period for both ears of veterans who had been fitted with a hearing aid monaurally at the Veterans Administration (VA) Hospital in East Orange, New Jersey. Scores did not change very much on the aided ear over the 5-year period, but declined significantly on the unaided ear. The authors termed this “late onset auditory deprivation.” Subsequent research confirmed that veterans who had been fitted binaurally initially tended not to show the deprivation effect on either ear. Aside from the obvious implication that binaural fitting should be the fitting method of choice, the deprivation effect emphasized that speech recognition ability is fragile in an ear with unaided sensorineural hearing loss. Could this explain the curious result of the Arkebauer et al. study? Did the greater loss in the poorer-hearing-ear, deprived of stimulation, actually interfere with the speech recognition ability of the better ear in the sound field condition until the poorer ear was plugged? Here was a strong argument for what has come to be called the “auditory

deprivation effect” (Silverman & Emmer, 1993) as one possible cause of what we now call “binaural interference.”

The term “binaural interference” first appeared in the audiological literature in a 1993 paper by Jerger, Silman, Lew, and Chmiel in the *Journal of the American Academy of Audiology*. This was a series of in-depth case studies of four individuals who showed strong signs of abnormal binaural processing. Data included W-22 scores, the auditory brainstem response (ABR), the auditory middle latency response (AMLR), and a behavioral task involving cued listening to continuous speech discourse in the presence of multitalker babble. The authors concluded that:

The exact mechanism of the binaural interference effect is not clear. It would appear, however, that by virtue of asymmetric distortion, either on a peripheral or central basis, the input to one auditory pathway suppresses or inhibits the input to the other pathway. (p. 130)

Over the next two decades, research in the area of binaural interference took one of two directions: analysis of either (1) speech recognition scores derived from group studies (Allen, Schwab, Cranford, & Carpenter, 2000; Henken, Waldman, & Kishon-Rabin, 2007; Karsten & Turner, 2000; Leigh-Paffenroth, Roup, & Noe, 2011; McArdle, Killion, Mennite & Chisolm, 2012; Mussoi & Bentler, 2017; Walden & Walden, 2005), or (2) a variety of auditory test data from individual case studies (Bellis, 2002; Carter, Holmes, 2003; Noe, Wilson, 2001; Jerger et al., 1993; Hurley, 1993; Jerger, Silman, Silverman, and Emmer, 2017; Silman, 1995).

GROUP STUDIES

Group studies have generally asked the question, “How many members of the group showed the unexpected pattern of bet-

ter monaural than binaural scores on a test of speech recognition?" Four of the studies cited above involved testing in the aided condition, whereas the remaining five involved testing in the unaided condition. The percentage of each group showing the binaural interference pattern varied from 0% to 82%, suggesting that many uncontrolled confounding variables were at work among the nine groups. The corrected median prevalence across groups was 19%, which agreed most closely with the experimental results of McArdle et al. (2012). (Table 5–1 in Chapter 5 details these nine studies). Although test conditions varied widely, and prevalence estimates covered a considerable range, two findings were fairly consistent: (1) the observations that the binaural interference pattern was more likely to occur in elderly listeners than in younger adult listeners, and (2) the conclusion that the degree of hearing loss did not appear to be a significant factor influencing prevalence of binaural interference. Finally, McArdle et al. argued persuasively that conclusions regarding the presence of binaural interference derived from aided sound-field testing are questionable unless the non-test ear has been plugged in the monaural test condition in order to prevent the unplugged, non-test ear from artificially inflating the best monaural test score.

Whereas possible binaural interference is an apparently significant issue in hearing aid use (McArdle et al., 2012; Walden & Walden, 2005) it is important to distinguish between binaural interference, in itself, and its possible effect on the hearing aid user. In the latter case, relating to hearing aid use, it is understandable that the "how many" question has been the paramount interest of group studies; but in the former case, relating to binaural interference, in itself, the more important question has been "why" the phenomenon occurs at all. Where in the auditory system does the breakdown appear? Here progress has depended not on group ("how many") studies, but on the analysis of intensive data from individuals who, by careful documentation, have been shown to reflect binaural interference.

CASE REPORTS

The most important difference between group studies and case reports is the extent of documentation of the reality of the binaural interference effect in an individual participant. In group studies, the data are usually confined to the three conventional speech-in-noise scores: monaural right, monaural left, and binaural (or their amplified equivalents, unilateral right, unilateral left, and bilateral). Binaural interference is then defined in an individual participant as the outcome in which the best monaural score exceeds the binaural score.

For the sake of our sanity through all of these numbers, mostly ours but yours as well, when summarizing aided results throughout this book, we will dispense with the distinctions between monaural and unilateral, and between binaural and bilateral. All aided results will still retain the traditional monaural and binaural nomenclature.

However, how can we be sure that this observed difference is not explainable by the error of measurement inherent in the percent correct scores? Here, the Thornton and Raffin (1978) 95% confidence intervals for scores are often consulted. Still one has the uncomfortable feeling that the decision to call an individual result “binaural interference” ought to be based on firmer evidence than two speech-recognition scores.

In case studies, however, the decision to accept test results as indicative of binaural interference is typically based on more than two speech recognition scores. The investigator seeks a common thread across two or more independent measures, and seeks, whenever possible, replicability. Likely suspects are abnormalities in the ipsilateral and contralateral acoustic reflexes, the auditory brain stem response (ABR), the masking level difference (MLD), the auditory middle latency evoked response (AMLR), the auditory late vertex response (ALVR), and directed-report measures of dichotic listening.
