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Rationale for Binaural Hearing Aid Fittings

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Few would disagree that people with refractory problems in both eyes should wear a pair of glasses. Yet, only a percentage of people with bilateral hearing loss wear binaurally fit hearing aids. There can be many reasons for the infrequency of binaural fittings. One of the main reasons, however, may be an incomplete understanding of the real necessity and advantages of binaural fittings. This paper summarizes the advantages of binaural hearing and binaural fittings, and provides some considerations when deciding between binaural and monaural fittings.

Binaural advantages: Psychoacoustic factors

a. Binaural loudness summation

Binaural loudness summation refers to the perceptual increase in the loudness of a sound when it is presented to both ears simultaneously as opposed to when it is presented to one ear alone (Reynolds & Stevens, 1951). This phenomenon is present in both normal and hearing impaired people, and its magnitude varies across individuals. At threshold, the increase in loudness is approximately 3 dB. When stimuli are presented at a suprathreshold level, the average increase in loudness is approximately 6 dB (Haggard & Hall, 1982).

There are many advantages that result from binaural loudness summation. Because sound is louder when heard in both ears, low intensity sounds that are not perceived in a monaural mode may become audible when the person is aided binaurally. Because less gain is required from each hearing aid to reach a comfortable listening level when the patient is aided binaurally than when aided monaurally, the chance of feedback is decreased and larger vents may be used (as appropriate) in a binaural fit. Less gain from the hearing aid also reduces the risk of saturation distortion. In addition, Levitt and Voroba (1980) reported that the binaural system has better frequency and intensity discrimination ability than the monaural system. These advantages may be responsible for reports of better sound quality and speech understanding (Balfour and Hawkins, 1992; Erdman & Sedge, 1981, 1986) when the wearers were aided binaurally rather than monaurally. The lower volume may also lead to lower current drain from each hearing aid, meaning longer battery life.

The loudness summation effect from binaural hearing aid use may solve some difficult-to-fit cases. One such case is a severe-to-profound degree of hearing loss. People with this degree of hearing loss may not get adequate amplification from one single hearing aid without risking feedback. Binaural hearing aid use would allow the wearer to enjoy comfortable loudness with lower risk of feedback.

b. Masking Level Difference (MLD)

A binaural system can utilize interaural time and intensity differences between ears to extract a signal from the noise background in order to increase its detectability over a monaural situation. This phenomenon is called Masking Level Difference (MLD, Hirsch, 1948; Licklider, 1948). The magnitude of MLD varies depending on the stimuli and comparison conditions. Levitt and Rabiner (1967) reported that the MLD for monosyllabic words can be as high as 13 dB.

The occurrence of MLD suggests that speech intelligibility in noisy situations may be enhanced with binaural fittings compared with monaural use. This effect has been demonstrated in hearing impaired individuals (Harris, 1980; Zelnick, 1970) and for both symmetrical and asymmetrical hearing losses (Markides, 1977). Hawkins and Yacullo (1984) showed that binaural hearing aid use improved the signal-to-noise ratio by about 3-6 dB over that of a monaural hearing aid condition. Because

speech understanding in noise has been reported as the major problem for hearing impaired people, it is incumbent upon all dispensers to fit binaurally for maximum speech understanding and hearing aid satisfaction.

Real-world hearing aid satisfaction surveys also reflected increased satisfaction from binaural hearing aid use. Kochkin and Kuk (1997) compared consumer satisfaction for binaural amplification in two groups of hearing aid wearers. One group wore conventional hearing aids (N=835), while the other group wore digitally programmable hearing aids (N=2237). Their results showed two interesting findings. First, binaural amplification yielded higher overall satisfaction than monaural amplification in both groups of subjects. Secondly, the group of subjects who wore programmable hearing aids reported 8% higher satisfaction for binaural fittings than monaural fittings in noisy situations. This suggests that enhanced hearing aid technology may also affect the degree of binaural preference.

c. Localization

Sounds that are generated in a sound field, arrive at the two ears at different times. Such difference in time of arrival gives rise to interaural phase and intensity cues which can be used to localize the sound source (Levitt & Voroba, 1980) as well as the angle of elevation of the source. In the median plane, it is estimated that normal hearing individuals can detect a difference in azimuth of as little as one degree (Zelnick, 1980).

The ability to localize the sound source is important in daily communication situations. For example, it alerts the listener to the location or source of potential danger in the environment, e.g., traffic. Often, the ability to communicate in noisy situations requires the listener to first identify the source of the sound. Binaurally fit hearing aids, especially those with the microphone inlets recessed into the concha-canal opening area (i.e., in-the-ear, in-the-canal, completely-in-the-canal), provide the hearing impaired person better localization ability (Westermann & Topholm, 1985). Kochkin and Kuk (1997) also showed that binaurally fit hearing aid wearers were about 15% more satisfied with their ability to tell the direction of sounds than those wearing a single hearing aid.

Other associated binaural advantages include stereophonic hearing, better sound clarity and quality (Balfour and Hawkins, 1992), and better speech understanding and sound quality perception in reverberant environments (Nabelek and Robinson, 1982).

d. Head shadow

Head shadow refers to the attenuation of sounds as they travel from one side of the head to the other. High frequency sounds are more affected because of their shorter wavelength. The effect can be as much as 15 dB at 4000 Hz (Sivian & White, 1933). Because vowels are primarily low frequency sounds and consonants high frequency sounds, the head shadow effect can significantly affect the recognition of consonants.

The consequence of head shadow can be substantial for a hearing impaired person. Consider the case when the desired speech signal is presented to the unaided ear of a monaurally aided person with a bilaterally symmetrical hearing loss. Because of the elevated threshold, the desired speech signal is not perceived at the unaided ear. Rather, it has to "cross over" the head to the aided ear for perception. In the process, the intensity of the high frequency speech sounds is diminished. This may affect intelligibility. Furthermore, because only one ear (i.e., the aided ear) perceives the speech signal, information on the direction of the sound is lost. In cases where noise is present on the aided side and speech on the unaided side, the speech signal originating from the unaided side will not be perceived in either ear because of threshold elevation on the unaided side and masking on the aided side.

Binaural hearing aid use eliminates any potential head shadow effect. In cases where the noise source is primarily from one side of the head, the wearer can turn the hearing aid off on that side to minimize any masking effect.

Neurophysiological necessity for binaural amplification?

a. Preservation of integrity

The integrity of a sensory system depends on external stimulation. Deprivation studies conclusively showed that sensory stimulus is needed for the structural development of sensory neurons as well as their functional connectivity (Webster & Webster, 1977). Studies on children's development showed that appropriate sensory stimulation, especially between the ages of 0 to 2 years, is critical for proper development in later years (Ross, Brackett, & Maxon, 1991). These studies illustrate the importance of binaural hearing on the proper speech, language, and cognitive skills of children, as well as providing the rationale for early identification, intervention, and binaural hearing aid fitting for children with hearing loss.

Until recently, it was a little known fact that adults may also suffer from sensory deprivation if their hearing losses are not properly managed. In a landmark report by Silman, Gelfand, and Silverman (1984), the authors demonstrated that hearing impaired people with bilaterally symmetrical hearing losses who were fit monaurally suffered a loss of speech recognition ability in the unaided ear (average loss of 18.5%). Subsequent reports by the same group of researchers (Gelfand, Silman, and Ross, 1987; Silverman and Silman, 1990) and

others (Burkey and Arkis, 1993; Gatehouse, 1989; Hood, 1990) also showed that such deprivation only occurred in the unaided ear of a monaurally fitted subject, but not in the unaided ears of a non-wearer.

Results from the deprivation studies have both fitting and legal implications. In order to avoid potential deterioration of performance in the unaided ear of a bilateral hearing loss, binaural hearing aid fitting is necessary. Legally, these results form a physiological basis that requires binaural amplification as the fitting standard in cases with aidable hearing loss in both ears. Departure from such practice may constitute malpractice and could be subjected to legal actions. Indeed, Lowe (1988) reported a case where an audiologist and an otologist were sued by a hearing impaired patient for failing to inform her of binaural amplification.

b. Bilateral tinnitus reduction

One effective approach to treat bilateral tinnitus in patients with associated hearing loss is the use of hearing aids (Brooks and Bulmer, 1981). Over 50% of hearing impaired people reported being less affected by their tinnitus when a hearing aid is worn on the affected ear. Masking of the tinnitus, and enhancement of hearing ability with hearing aid use are often quoted as the reasons for the noted tinnitus relief. In cases of bilateral tinnitus but monaural hearing aid use, the hearing impaired person may report suppression of tinnitus on the aided ear, but noticeable tinnitus on the unaided ear. Binaural hearing aid use may be extremely beneficial for bilateral tinnitus.

c. Consumer report

- **Ease of listening comfort**

Consumer surveys of binaural hearing aid wearers also revealed that a major advantage is the improved ease of listening with binaural hearing aids (Brooks and Bulmer, 1981; Briskey and Cole, 1983; Erdman and Sedge, 1986; Chung and Stephens, 1986). Zelnick (1985) also reported that hearing impaired people were more relaxed and experienced less tension in listening situations when aided binaurally compared to monaurally.

- **Preference over monaural fitting**

Most surveys comparing monaural/binaural amplification favored binaural amplification (e.g., Briskey and Cole, 1983; Chung and Stephens, 1986; Erdman and Sedge, 1986; Jordan et al, 1967). The preference for binaural was found regardless of the experience of the hearing aid wearers, their gender, the symmetry of their hearing loss, and whether they paid for the hearing aids.

A recent large scale (over 3,000 respondents) consumer survey also confirmed these findings. Kochkin and Kuk (1997) compared consumer satisfaction between binaural and monaural hearing aid wearers in the USA. The results of the survey showed that more binaural hearing aid wearers were satisfied with their hearing aids than monaural hearing aid wearers. The advantages of binaural fittings over monaural fittings included the ability to localize sounds, longer battery life, better performance in noise, better sound quality, and higher satisfaction in specific listening situations like one-on-one, small and large groups, and outdoors. These findings confirm the theoretical advantages of binaural amplification discussed previously.

Candidates for binaural amplification

The psychoacoustic advantages and neurophysiological necessity of binaural hearing aid fittings led many clinicians and researchers (e.g., Hawkins, 1986; Skinner, 1988) to suggest that hearing impaired people with aidable hearing loss in both ears should be considered candidates for binaural amplification. This view had been questioned in the past.

a. Symmetry of hearing loss

Some authors (Markides, 1977; Davis and Haggard, 1982; Gatehouse and Haggard, 1986) have suggested that binaural amplification should be recommended only to people with symmetrical hearing loss who have less than 15 dB difference in threshold and less than 8% difference in speech recognition scores between ears. Substantial difference in the values of suprathreshold indices (like MCL and LDL), and hearing loss configuration (flat in one ear and precipitous in other ear) were also cited as contraindications for binaural amplification.

On the other hand, some reports suggested that symmetry of hearing loss should not be a factor in considering binaural candidacy (Chung & Stephens,1986; Hawkins, 1986; Moncur & Dirks, 1967). This is because the criterion of ear symmetry does not consider the ability of the auditory system to integrate and process information received from both ears. Clinically, it is frequently observed that a majority of people with asymmetric hearing loss enjoy good (or even better) speech recognition and sound quality judgments when they are aided binaurally compared to monaurally, even though one ear has significantly poorer sound quality and speech intelligibility scores when it is aided alone. Furthermore, these patients are able to report many of the advantages of binaural amplification. These

comments are possible because of the integration of information from both ears.

Similarly, the criterion for binaural amplification cannot be determined simply based on threshold and/or suprathreshold information on each ear alone (exception: dead ear). Rather, such a decision must be based on an evaluation of binaural fusion in the impaired auditory system, a process that is dependent on the central auditory processing capability of the hearing impaired individual.

There is not yet a standard protocol to determine fusion for the purpose of binaural amplification. However, one relatively simple clinical procedure may have some merits (Mercola and Wenke-Mercola, 1985). In this procedure, speech is presented to both ears of the hearing impaired listener until it is at a comfortable listening level (levels may be different between ears). Those who can maintain a midline image are considered potential candidates for binaural amplification. Those who report separate images at each ear, despite careful adjustment of presentation levels, would not be good candidates for binaural amplification. In such cases, the ear with a better speech recognition score and/or better sound quality will be aided. In the case of a "dead" ear, CROS (Contralateral Routing of Signal), BiCROS (Bilateral Contralateral Routing of Signal), or Power-CROS are suitable alternatives to monaural hearing aids. (See Skinner, 1988 for a description of their proper use.)

b. Age: central processing ability & dexterity

Rousch (1985) reviewed several reports on the performance of the binaural system in different age groups and reported that the binaural system was resistant to distortion and that there was no difference in performance between elderly and younger subjects on binaural tasks. Grose (1996) also reported that, although elderly persons showed reduced binaural advantages, there remained significant benefits for the elderly hearing impaired person when listening with both ears instead of one. These reports showed that age, despite the reduced potential central processing ability seen in some elderly people, should not be a limiting factor in binaural fitting.

However, the physical and cognitive ability of elderly individuals to handle their hearing aids may limit their successful use. Fortunately, technologies are available today that simplify the use of hearing aids. Some digital and digitally programmable hearing aids can automatically adjust their volume and frequency responses to adapt to the changing listening environments. Some programmable hearing aids also come with a remote control that obviates the need for external volume adjustment. A detailed evaluation of the needs of the hearing impaired person, and the application of proper technology could ensure that these individuals enjoy all the benefits provided by binaural amplification.

c. Cost and other factors

Other factors are important to consider in the recommendation of binaural hearing aid use. Clearly, those with a severe loss must wear two hearing aids to ensure adequate output (Day, Browning, Gatehouse, 1988). Children with bilateral hearing loss should be amplified binaurally as early as possible in order to maximize their learning potential. It is gratifying to note that such practice is widely adopted in many countries (Byrne & Upfold, 1986; Duffy, 1980; Ross, 1980).

Cost is often cited as a factor in binaural recommendation (Schreurs & Olsen, 1985). However, Kochkin (1992) showed that cost is the least important factor in a consumer's perception of their hearing aid satisfaction. Improved hearing, especially in multiple listening environments, is the key factor governing satisfaction. In another study, Kochkin and Kuk (1997) showed that consumers who were fit binaurally with programmable hearing aids perceived their hearing aids to be of "higher value" (cost vs. benefit) than monaurally fit hearing aids. If our goal in hearing aid fitting is to improve the patient's communicative ability and their satisfaction towards hearing aids, we should not let our perception of the cost of the hearing aid be the primary factor that determines our recommendation for the patient. Rather, inform the patients of binaural benefits and let them make the decision.

A Summary

Binaural amplification is gradually being accepted as the norm in hearing aid fitting in many countries because of its noted performance advantages and neurophysiological necessity. Progress in hearing aid technology has helped to realize some of the theoretical advantages of binaural fittings. Such benefits include: better speech understanding in quiet and in noise, better sound quality, better localization of sounds, avoidance of the head shadow effect, and higher listening comfort in various situations. Binaurally fit hearing aids are also effective in the management of bilateral tinnitus in some patients and in potentially preserving the integrity of the binaural auditory system.

In order for hearing impaired people to benefit from binaural amplification, it is important that hearing healthcare professionals select the appropriate technology and counsel their patients on binaural benefits properly. The hearing impaired person has the right to know why binaural fitting may be more appropriate for his degrees of hearing loss.

Appropriate candidates for binaural amplification should include all hearing impaired people with measurable hearing loss in both ears. The overriding criterion is that the central auditory system can integrate auditory images from both ears to form an undistorted, midline image. Although the ultimate decision maker of binaurality is the hearing impaired person, the hearing aid dispensers play a critical role in determining if the patient has the chance to make the monaural/binaural decision. Perhaps an adjustment period may be allowed so that the hearing impaired person can experience the difference outside the clinic before a decision on the mode of fitting is made (Hawkins, 1986; Skinner, 1988).

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