Fitting Strategies for Patients with Symmetrical Hearing Loss

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Introduction

Patients with a bilaterally symmetrical sensorineural hearing loss are commonly seen in clinics and are candidates for binaural amplification. Fitting them with monaural amplification should be the exception to the rule and the reason should be carefully noted because they will lose a variety of potential advantages (described below) that come with bilateral hearing. Many patients continue to come to the clinic hoping to need only one hearing aid, so the audiologist is challenged to present a concise explanation as to why binaural amplification is superior. Most patients and family members understand the need for binaural hearing once it is explained. Interestingly, many patients who have to be monaural hearing aid users when one of their binaural hearing aids are sent in for repair will be the first to describe the superiority of hearing with two ears.

MarkeTrak V (Kochkin, 2000) surveyed hearing aid users on a variety of dimensions including 45 ratings of consumer satisfaction with hearing aids and hearing health service. Individuals with bilateral hearing loss were divided into groups wearing monaural and binaural hearing aids. Among items that would be impacted by binaural hearing (large groups, sound of your own voice, car, outdoors, small groups, hearing soft sounds, and localization), binaural hearing aid users reported 8 to 14% more satisfaction than monaural hearing aid users. Kirkwood (2001) reported that binaural fittings have increased each year over the past 5 years. On average, hearing aid providers reported that 71% of their fittings were binaural in the year 2000 compared with 68% reported in 1999. Perhaps it is most appropriate to consider binaural amplification in the context of the overall goals of a hearing aid fitting.

Goals of the Hearing Aid Fitting

Most researchers and clinical audiologists would agree that there are five basic goals of a hearing aid fitting: (1) sounds at various input levels should be audible across frequencies, (2) sounds at various input levels should not be uncomfortable, (3) sounds should have good sound quality, (4) the amplification should provide a safe listening environment, and (5) the amplification should meet the patient’s communication needs and expectations. Providing binaural amplification for the bilaterally hearing-impaired patient impacts our ability to meet at least four of these goals. The relationship
of binaural hearing to our hearing aid fitting goals is described in the following sections.

**Hearing with Two Ears**

The phenomenon of binaural hearing has been thoroughly investigated (reviewed in Durlach and Colburn, 1978; Valente, 1982; Hausler et al, 1983) for both normal-hearing and hearing-impaired listeners. Most binaural phenomena arise as a result of the two ears being located at either side of the head. The head is a sphere with the ears positioned in the horizontal plane at opposite poles (Fig. 7–1). Because of this arrangement, sound arriving from a source will be slightly different at the two ears. These differences will exist in intensity as a function of frequency and time. These differences are caused by the physical positioning of the ears and are present for children and adults, for individuals with unilateral and bilateral hearing loss, and for individuals with normal and compromised central auditory nervous system (CANS). The ability to take advantage of these differences is dependent on the status of the periphery and CANS. Localization, improved hearing in noise, lower gain requirements, ease of listening, improved sound quality, and preservation of hearing abilities are all considered advantages to listening with two ears in the sound field. These characteristics and related psychoacoustic phenomena are discussed below as they relate to the five goals of the hearing aid fitting.

**Locating a Sound Source**

Identifying the location of a sound is important for sensing the environment and feeling safe and secure and has significance in a patient’s everyday hearing difficulty (Noble et al, 1995). The interaction of the sound wave with the physical attributes of the listener and the environment allows for spatial and spectral cues that the individual uses to locate sound (reviewed in Mills, 1972). The ability to localize impacts goal 4 (listed above) of the hearing aid fitting: the amplification should provide a safe environment. Knowing where sound is arriving from also contributes to people’s perception of where they are in relation to the rest of the world (spatial organization). Without this sense, patients may complain of being off balance or describe symptoms of disequilibrium.

**Interaural Time Differences**

The head separates the two ears by a particular distance. Depending on the location of the sound (azimuth in the horizontal plane), the sound will reach one ear first (the near ear) and reach the second ear (the far ear) a short time later. The largest difference occurs when the azimuth is ±90 degrees (Fig. 7–1). The maximum time difference of approximately 0.65 msec varies with the exact diam-

![Figure 7–1. Locations of sound sources are expressed as azimuths in the horizontal plane.](image-url)
eter of the head and the speed of sound (sound travels a little more than 1 foot each msec). The time difference decreases as the azimuth decreases and is zero at 0-degree azimuth (Fig. 7–1). The difference between the ears in time of arrival of a speech signal will create phase differences between ears—how much of a phase difference will depend on the particular frequency.

**Interaural Intensity Differences**

When a sound wave encounters an obstacle, it will reflect off the object or bend (diffract) around the object. If the dimensions of the object are large compared with the wavelength of the sound, the wave reflects off the object. The resulting difference in dB between the two ears depends on the azimuth and the frequency (wavelength) of the source (Shaw 1966, 1974). High frequencies have short wavelengths, therefore reflecting off of the head and creating the largest interaural (between ear) differences. Very little high-frequency sound reaches the far ear (Fig. 7–2). Low frequencies bend around the object, creating small interaural intensity differences (Fig. 7–2). For example, there will be a 9-dB difference between ears when a 1000-Hz signal is presented at a 40-degree azimuth (Fig. 7–2).

The medial olivary complex of the brainstem is said to be the site at which afferent impulses from the two ears first meet (Nilsson and Liden, 1976). It is at this point that the spectral cues of time/phase and intensity differences between the two ears are compared and begin to be used to locate the source of sound in one’s environment. Patients truly hear with their brains, not with their ears alone. The brain requires binaural input to do the best possible job in locating sounds and in understanding speech in noise.

**Hearing in Noise**

When an individual is listening with only one ear (either with unilateral hearing loss or monaural amplification), he or she will

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**Figure 7–2.** Interaural intensity differences (dB) as a function of azimuth and frequency. For example, at ±90 degrees, one source is placed directly in front of the right ear and the other in front of the left. At 4000 Hz, the ear difference would be 13 dB. (Data from Shaw, 1974.)
try to manipulate the listening environment so that the good ear is the near ear (closest to the source). This is not always possible (especially in group communication), so the good ear will sometimes be the far ear. When this occurs, there will be a large communication disadvantage because of the head shadow effect. Figure 7–3 shows the large disadvantage that can be imposed by the head shadow. Thresholds for spondee words were obtained for normal-hearing individuals at different azimuths. In the monaural conditions, one ear was occluded (creating one good ear). Figure 7–3 compares near-ear and far-ear listening to binaural listening. Even at 0-degree azimuth where there is no near or far ear, both monaural thresholds were about 3 dB poorer than for the binaural condition. Elimination of the head shadow is a very important aspect of binaural hearing. Reducing threshold (e.g., by 10 dB at 60-degree azimuth when comparing binaural listening to far ear monaural listening, see Fig. 7–3) is equivalent to increasing the sensation level of speech (in this example by 10 dB). Depending on the listening environment, this can mean a substantial improvement in intelligibility (up to 50%, Olsen and Matkin, 1979).

There is an additional benefit from eliminating the head shadow through binaural hearing when speech is presented in noise (some competing message), provided that the speech and noise come from different azimuths. In most communication situations there is noise present, and it rarely arrives from exactly the same azimuth as the signal of interest (by virtue of how patients place themselves in their communication environments). When speech and noise are spatially separated, a binaural advantage of up to 11.5-dB signal-to-noise ratio (SNR) exists.

![Figure 7-3](image-url)

**Figure 7-3.** Spondee thresholds as a function of azimuth. Positive azimuths represent monaural listening with the good (open) ear in the far ear condition. Negative azimuths are for the open ear when it is in the near ear condition. Thresholds for both of these monaural conditions are compared with binaural thresholds (when both ears were open). Near ear and far ear thresholds were poorer than binaural thresholds. (Data are from Dirks and Wilson, 1980.)
The improvement in SNR reflects a combination of elimination of the head shadow effect and *binaural squelch* (the central nervous system’s ability to compare the signals being received at each ear).

With all of the noise cancellation systems introduced by the manufacturers of hearing aids, the most impressive and effective noise cancellation system is the CANS. Most listening environments contain at least one noise source. In a reverberant sound field, echoes further complicate the listening environment. When the speaker is fairly close to the listener [within the critical distance (Nabelek, 1980)], incident sound is more intense than the reflections. The interaural phase and intensity relationship will be different for the speech versus the noise. The CANS uses these differences to improve speech intelligibility. Whenever the speech and noise are different at the two ears, the signal can be enhanced and the noise can be cancelled.

Improvement in intelligibility in noise when a monaural listening condition (good ear serving as the near ear to the speech) is compared to a binaural listening condition is called *binaural squelch*. It is interactions between the ears for lower frequencies (1000 Hz and below) that are most important for creating the squelch effect. Cox and Bisset (1984) reported a 2- to 3-dB advantage in SNR for their aided hearing-impaired subjects when listening in the binaural as compared to the monaural condition. In other words, the SNR could be 2 to 3 dB worse in the binaural listening condition and the subjects would achieve the same intelligibility score as the monaural listening condition.

Elimination of the head shadow effect and binaural squelch serve to aid in achieving goal 5 of the hearing aid fitting: the amplification should meet the patient’s communication needs and expectations. The main concern of most patients with moderate, bilateral, sensorineural hearing loss is difficulty understanding in noisy environments, and this often becomes the patient’s primary expectation from the new hearing aids.

### Binaural Summation

The threshold for a signal presented diotically (i.e., identical signals at the two ears) via earphones is better than that for a signal presented monaurally. There is a 2- to 6-dB advantage. At suprathreshold levels, there is approximately a 9-dB advantage for normal hearing listeners. This difference, called *binaural summation*, is an advantage when fitting hearing aids because less gain is needed in each ear to achieve the same perception of loudness. Less gain allows targets to be reached more easily with a wider variety of hearing aid styles and circuits and produces less chance of feedback. Feedback is produced when amplified sound can escape from the ear canal and reach the microphone (to be reamplified). With less gain, there is less chance that amplified sound will be intense enough to reach the hearing aid microphone.

The 3-dB binaural summation value (Dirks and Wilson, 1980) may be used in hearing aid fitting strategies for a binaural fitting. The prescription provided by the fitting strategy would automatically decrease gain by 3 dB if the audiologist indicates that the fitting is binaural. This value is obtained from normal hearing individuals at threshold, so it may not be entirely accurate for manipulating hearing aid fittings that apply to individuals with sensorineural hearing loss who are listening at suprathreshold levels the majority of the time. Many prescriptive formulas do not include a binaural correction (see Chapter 1) for coupler or real-ear verification targets, so the audiologist must be aware that monaural targets prescribe more gain than is needed for the binaural fitting. Valente (1983, 1984) indicated that suprathreshold binaural summation is even greater than binaural summation at threshold. Further data are required (and perhaps individual data would be ideal) to identify how much of a gain reduction is appropriate for a binaural hearing aid fitting. More appropriately, audiologists might need to think of how much more gain is needed for a monaural fitting. Binaural summation assists in meeting goal 1 of our
hearing aid fitting: sounds at various input levels should be audible across frequencies.

**Ease of Listening**

Another advantage of binaural listening is ease of listening, which may be measured as a subjective benefit. A measurement of response time also sheds light on the ease of understanding a speech signal. The assumption is that when the patient is confident about what was said, the response will come more quickly. Aided listeners do have shorter response times when aided binaurally rather than monaurally (Causey and Bender, 1980; Feurstein, 1992). Ease of listening may contribute to obtaining goal 5 of the hearing aid fitting: the amplification should meet the patient’s communication needs and expectations. Many individuals with hearing loss experience fatigue from straining to understand communication. Any reduction of this fatigue would address a variety of communication needs. This is especially important for some young listeners who need to have cognitive reserves left over for processing all of the new information that they are hearing in their learning environments.

**Sound Quality**

Balfour and Hawkins (1992) asked 15 adults to judge the sound quality of speech and music in quiet and in noise in a test booth, living room, and lecture hall. Binaural listening was preferred for speech and music in quiet and for speech in +10 SNR. The listening environment had no effect on the sound quality ratings. One critical finding of this research was that a paired comparison of monaural to binaural listening was required for subjects to notice the binaural advantage. This implies that a trial with monaural amplification followed by a trial with binaural amplification (or vice versa) may not be adequate for the listener to perceive the advantage of binaural sound quality. Improvement of sound quality for higher level signals will aid in meeting goal 2 of the hearing aid fitting: sounds at various input levels should not be uncomfortable. Good sound quality also should be an expectation of the individual pursuing amplification (goal 5).

**Preserving Hearing**

Over the past decade, a variety of authors have reviewed the area of auditory deprivation (Moore, 1993; Neuman, 1996; Palmer et al, 1998). Arlinger et al (1996, p. 875) define the auditory deprivation effect as the “systematic decrease over time in auditory performance associated with the reduced availability of acoustic information.” Over the past two decades several investigators have reported a late-onset auditory deprivation or nonstimulation effect in unaided ears of monaurally aided hearing-impaired individuals (Silman et al, 1984; Gelfand et al, 1987; Gatehouse, 1989; Silverman, 1989;Stubblefield and Nye, 1989; Hood, 1990; Silberman and Silman, 1990; Hurley, 1991, 1993; Boothroyd, 1993; Burkey and Arkis, 1993; Gelfand and Silman, 1993; Hattori, 1993; Silman et al, 1993; Silverman and Emmer, 1993; Gelfand, 1994, 1995; Poole and Jerger, 1994; Robinson and Gatehouse, 1995).

The term *late-onset auditory deprivation* was coined by Silman et al (1984) to describe the 40% of the monaural hearing aid wearers in their retrospective study who had reduced word-recognition scores in their unaided ear after a period of asymmetrical stimulation. Late-onset indicates that these findings were in developed, adult systems as opposed to developing, young systems. Deprivation refers to the loss of stimulation of the unaided ear after the monaural hearing aid fitting and to the subsequent reduction in the patient’s ability to recognize words even when presented with an audible signal. Four of the studies investigated recovery after asymmetrical stimulation. Partial recovery in word recognition ability after fitting the nonstimulated ear of a monaural hearing aid user was reported in all four studies. A lack of recovery, however, was reported for other subjects in each study.

The amount of recovery varied greatly between individuals, and some individuals refused to try the binaural configuration
because they complained that the new input was getting in the way of the other ear. This latter reaction is termed binaural interference by Jerger et al (1993). Although case studies have been reported (Jerger et al, 1993; Chmiel et al, 1997; Jerger, 2001) documenting the existence of binaural interference in some patients (inability to use a binaural signal), these cases appear to be rare. There is some question as to whether an audiologist should consider a screening test to verify that the patient can benefit from binaural amplification or whether the lack of benefit after a brief trial will be self-evident. In addition, the recovery data reviewed above suggest that some individuals who show binaural interference initially may recover binaural ability if they can acclimatize themselves to wearing the binaural hearing aids long enough. This is an area that will require more basic and applied research to further define the abilities of the auditory system and the clinical protocols that will best serve the patient.

One can assume that a monaural fitting of a bilateral hearing loss in a child might be even more detrimental than that of an adult because auditory pathways continue to develop depending on stimulation patterns in the young child. Hattori (1993) and Boothroyd (1993) provide compelling data that monaural amplification is not adequate in the developing system if the goal is to develop a functioning binaural system that can take advantage of the binaural benefits described earlier. The best practices suggest that binaural amplification is mandatory in the majority of children with bilateral hearing loss to ensure the best possible development of the auditory system and to provide them with the most benefit in their social and educational communication environments.

Animal data support the notion that disuse of the central auditory pathway can result in a combination of peripheral hearing loss, lack of acoustic stimulation, and adverse effects on the development of the central auditory system. Neuroscientists have investigated the adaptive properties of the central auditory system in animals by creating peripheral lesions mechanically (Robertson and Irvine, 1989; Rajan et al, 1993), ototoxicly (Schwaber et al, 1993; Popelar et al, 1994), or via exposure to intense noise (Kaitenbach et al, 1992). Other researchers have studied changes in the central frequency representations of inbred mice that are genetically programmed to develop progressive presbycusic-like sensorineural hearing loss similar to that observed in humans (Willott, 1984; Willott, et al, 1991, 1993). The animal data support the notion that deprivation of auditory input causes changes in the central auditory pathway.

When one reviews all of the findings, it appears that both auditory deprivation and recovery occur in some individuals. Perhaps more than the other advantages to binaural hearing, this disadvantage of a lack of binaural hearing (along with safety, which could be associated with localization abilities) requires careful documentation by the audiologist if the patient refuses binaural amplification. The patient’s chart should contain a note indicating that the potential benefits of binaural amplification were explained and that binaural amplification was not selected for one of several reasons (e.g., medical contraindications, an unaidable ear, financial reasons, or refusal by the patient). Another method of documentation could include a form that reviews several patient options including binaural listening (a sample of such a form is included as an appendix to this chapter; see also Palmer and Mormer, 1997). The patient’s signature verifies that he or she understands the potential benefits of binaural listening and the potential hazards of monaural listening (Fishbein, 1991).

**The Binaural Advantage for Listeners with Hearing Loss and with Hearing Aids**

Although binaural advantage has been defined for normal hearing listeners, it is listeners with hearing loss who seek amplification. Many of the benefits discussed here are experienced by hearing aid users if their hearing aids create audible signals for soft, moderate, and loud sounds across a wide
range of frequencies. Audibility for all levels of sounds and for the majority of frequencies is dependent on the individual’s hearing loss and the hearing aid technology. An understanding of binaural listening helps the audiologist develop realistic expectations of binaural advantage given the individual’s aided results.

Generally, individuals with hearing loss produce patterns of performance similar to their normal hearing counterparts on auditory tasks involving speech perception, but they may not perform as well. Hearing loss produces distortion in the system, and hearing aids used to increase audibility for the listener add their own level of distortion in the form of time delays and phase changes that might negate any binaural advantage. It is reasonable to ask whether individuals with hearing loss pursuing hearing aids will be able to benefit from binaural hearing. Although aided listeners do not perform as well as their normal hearing peers, the binaural advantage is present and worthwhile.

A variety of researchers have demonstrated a binaural advantage produced by both the elimination of the head shadow effect and binaural squelch in subjects with aided and unaided hearing loss (Markides, 1977; Hawkins and Wightman, 1980; Cox et al, 1981; Hawkins and Yacullo, 1984; Bronkhorst and Plomp, 1990; Leeuw and Dreschler, 1991; McCullough and Abbas, 1992; Noble et al, 1994, 1998). The limiting factor appears to be the amount of high-frequency hearing loss and the ability to restore audibility across frequencies.

**Impact of Directional Microphones on Binaural Listening**

Directional microphones became popular on behind-the-ear (BTE) style hearing aids in the late 1970s. Directional microphones can have a variety of response patterns, but generally the individual’s hearing aid picks up sound toward the front more than sound from the back. Directional microphones were introduced to further enhance the SNR for the hearing-impaired listener. Hawkins and Yacullo (1984) found that the directional microphone advantage is greater than the binaural advantage for aided individuals. This means that there is an advantage to listening in noise with two hearing aids and an even larger advantage with the use of directional microphones on the two hearing aids. Directional microphones did not receive much more attention in the 1980s because custom products became the most popular styles, and until the 1990s directional microphones could not be used with in-the-ear (ITE) products.

With renewed interest in directional microphones as they were applied to custom products, Leeuw and Dreschler (1991) also found that directional microphones provide more benefit than binaural amplified listening alone. There are no data to compare monaural directional listening in noise as compared with binaural (nondirectional) listening. Based on current data, one would recommend binaural listening (with or without directional microphones) as superior to monaural listening (with or without a directional microphone). Chapters 2 and 7 in the companion book *Hearing Aids: Standards, Options, and Limitations, 2nd edition* provide a detailed description of the technology and use of directional microphones.

The focus of directional microphones has been on listening in noise. The impact of directional listening on individuals’ ability to localize or spatially orient themselves has not been investigated. Although we may be enhancing the binaural advantage for listening in noise, we may be sacrificing other binaural advantages (e.g., localization) with the use of directional microphone technology.

**Impact of Aging on Binaural Listening**

The elderly population must be considered in a discussion of binaural benefits. Because a great number of individuals experiencing hearing loss and pursuing amplification are aging adults, the impact of aging alone on binaural abilities is of interest. Koehnke and Besing (2001) provide a thorough review of the effects of aging on binaural and spatial
tasks. Their review indicates that the ability of older listeners to localize sound sources, obtain a gain in speech intelligibility in noise when speech and noise sources are separated, improve the detection of signals in noise by using binaural cues, and discriminate interaural differences in time and intensity decline with increasing age (even when the effects of hearing loss have been controlled).

As with peripheral hearing loss, any disturbance in central processing can compromise, but usually not eliminate, the benefits associated with binaural processing. Kricos et al (1987) found no relationship between perceived hearing aid benefit and central auditory function in a group of 24 aging subjects. Helfer (1992) studied the performance of a group of nine older (>60 years) adults listening in a simulation of a realistic, noisy (+10-dB SNR), reverberant environment. She found that their performance was similar to that of young, normal-hearing individuals. Although the presence of reverberation reduced benefit, the older adults were able to take advantage of binaural cues to achieve improved intelligibility over the monaural condition. The audiologist and patient should understand the potential impact of age on the realistic expectations of the hearing aid fitting.

**What Do We Need to Know about the Auditory System and the Person?**

The comprehensive audiologic evaluation will produce information regarding symmetry between the ears in terms of thresholds and word recognition. Standard word recognition scores must be considered in light of Thornton and Raffin’s (1978) data that indicate that a large difference is required in word recognition scores before one can consider the scores truly different. Word recognition should be considered valuable for diagnostic purposes (red flag for potential retrocochlear problems) and perhaps for generating realistic expectations. Assuming proper diagnostics have been attempted on an individual with asymmetric word recognition scores (e.g., auditory brainstem response audiometry), binaural amplification can be attempted. Even an ear that receives very little benefit alone may produce a large increase in benefit to another more “aidable” ear.

Although authors have recommended that the audiologist assess potential binaural interference (Jerger et al, 1993; Chmiel et al, 1997), no particular assessments appear to be used in any standard way. It has been suggested that monaural and binaural word recognition scores be compared, but word recognition is not sufficient to allow for this type of careful comparison (i.e., too great a difference is required to believe that the two conditions are truly different). Binaural interference will become evident over the course of a trial with binaural amplification through patient report.

Measuring performance in noise is becoming more popular as two convenient, reliable measurement tools have become available. The Speech in Noise test (SIN, Etymotic Research, 1993) and the Hearing in Noise Test (HINT, Soli and Nilsson, 1994) evaluate an individual’s understanding in noise. These tests could be presented both monaurally and binaurally to counsel the patient prior to ordering binaural hearing aids or as a verification measure postfitting. For selection/counseling purposes, a SIN score (speech and noise presented at 0-degree azimuth) could be obtained with monaural and binaural listening. The scoring procedure results in a dB SNR in each condition. The condition that requires a smaller SNR is superior. An example of a verification technique might include using the HINT. The noise could be presented to the aided ear with the speech directed toward the unaided ear. The SNR required to function at a particular criterion is obtained. Then the patient can be aided binaurally with the same signal arrangement. A second SNR score is obtained. The two scores can then be compared.

In addition to demonstrating binaural advantage in noise, these tests can further assist in technology decisions and/or in providing the patient with realistic expectations of hearing in noise considering the technology for which they are asking. For instance,
very poor ability in noise might encourage a recommendation of binaural, directional microphones and/or assistive listening technology. If the patient is insisting on monaural, conventional technology, this type of testing may help the patient adjust his or her expectations of performance in noise.

It is possible to measure an individual’s binaural summation and to use this value in modifying the hearing aid fitting. The audiologist could present a signal through the sound field with one ear occluded and then with both ears open and determine threshold. The audiologist would have to decide which frequencies to assess (or should speech be used), and whether threshold data are appropriate for modifying a hearing aid prescriptive target. Another approach might be to obtain loudness discomfort levels (LDLs) in the monaural condition (one ear occluded) and in the binaural condition to assess how much reduction will be required for the maximum output of the fitting. Given the use of programmable technology, the clinician’s time may be better spent modifying the hearing aid program during verification rather than making this upfront measurement.

If the audiologist needs to convince the patient of the benefits of binaural amplification, use of the Abbreviated Profile of Hearing Aid Benefit (APHAB, Cox and Alexander, 1995), the Client Oriented Scale of Improvement (COSI, Dillon et al, 1997), and/or the Patient Expectations Worksheet (Palmer and Mormer, 1997) may assist in counseling. The APHAB will highlight communication situations that are impacted by noise and/or localization and therefore will be impacted by binaural hearing aid use. If the individual’s scores reveal difficulty in these situations, a recommendation for binaural amplification is warranted. The COSI and Patient Expectation Worksheet provide the audiologist with a systematic method for qualifying the patient’s primary expectations. In most cases, hearing in some type of noisy situation will be among the top five expectations. Once again, binaural amplification should be pursued or patient expectations should be modified.

**Preparation for Binaural Amplification**

Precounseling for Binaural Hearing

The needed counseling regarding binaural fittings will vary depending on the intended user. New users will need to understand that with both ears occluded, their own voice will sound different. The audiologist should provide a long ear canal portion of the earmold with a custom shell (Killion et al, 1988) and as much venting as possible based on the hearing loss to reduce the occlusion effect. The new user of technology that will make soft, moderate, and loud sounds audible across frequencies should be warned that soft sounds will now be audible and may be distracting for the first couple of weeks. With the increased use of expansion (less gain for quieter signals—the opposite of compression) for very quiet signals, the audiologist may be able to reduce the overwhelming perception of very soft sounds. Previous monaural amplification users will need similar counseling and may need added encouragement to wear the new hearing aid if they have experienced any type of auditory deprivation over time in the unaided ear.

**Preselection Decisions**

Preselection decisions include style, technology, and earmolds. Some of these parameters relate to the decision to amplify an individual binaurally. For instance, it is advisable to provide a telecoil on each hearing aid (for BTE and ITE styles) so patients will have the freedom to use either ear on the telephone, but more importantly so they will continue to receive binaural benefits if they use assistive technology. Although there will no longer be benefits related to head shadow and binaural squelch when a signal is transmitted from a microphone via FM signal to a receiver that is coupled to the hearing aids, there is still potential benefit in binaural summation and ease of listening. The same decision would apply to selecting direct audio input (it should be available on both hearing aids). Direct audio input allows the user to connect the hearing aid through a wire to the receiver portion of an assistive listening device. This
type of connection uses the internal hearing
aid signal processing as opposed to the tele-
coil coupling that is separate circuitry.

If individuals with moderate sensorineu-
ral hearing loss have decided to pursue the
new middle ear implantable hearing aids
(Chasin, 1997), they most likely will receive
only one hearing aid at this point in time. Al-
though this new surgical procedure boasts
a removal of the occlusion effect and elimi-
nation of feedback problems as well as cos-
metic advantages, a loss of binaural hearing
may not be worth the other advantages. This
is something the audiologist and patient
will have to discuss as the middle ear im-
plantable hearing aids become more widely
available. See Chapter 11 for an in-depth dis-
cussion of middle ear implantable systems.

Hearing Aid Fitting Strategies

Byrne (1981, 1986) and Libby (1991) suggest
that binaural hearing aids are fit the same
way as monaural hearing aids. The selection
procedure is performed with each ear sepa-
rately. Skinner (1988) suggests that there are
two approaches to fitting hearing aids binau-
rally. The first consists of a period of adjust-
ment with a monaural fitting before the bin-
aural fitting. The second consists of two
hearing aids being fit initially. The recom-
modation for an adjustment period with
only one hearing aid comes from the belief
that listeners will have more difficulty ad-
justing to two hearing aids. In a study by
Cook (1983), three groups of hearing aid
users (monaural users, monaural transi-
tioned to binaural users, and binaural users)
showed no statistical differences in adjust-
ment difficulty. This study did not support
the belief that hearing aid users will have
more difficulty adapting to two hearing aids.

Punch et al (1991) evaluated three strate-
gies for fitting binaural hearing aids on in-
dividuals with symmetrical sensorineural
hearing loss. The strategies included using
preferred frequency shaping and noise re-
duction values binaurally (1) based on
monaural testing, (2) based on separate eval-
uations of each ear, and (3) based on evalua-
tion of a second ear while subjects wore a
previously programmed hearing aid in the
first ear. Results showed that with this group
of subjects, the first fitting strategy is accep-
table. This is the most time-efficient of the
three methods. Additionally, the researchers
found that subjects adequately achieved in-
teraural intensity balance by adjusting their
volume controls. This implies that for hear-
ing aid users equipped with volume con-
trols, minimal time needs to be spent in bin-
aural balancing. This will not be the case for
individuals without volume controls who
will depend on clinical manipulation of
the hearing aids to achieve a balanced per-
ception.

To compensate for binaural summation
discussed in a previous section), gain is
often reduced by 3 to 6 dB across frequen-
cies (Pollack, 1988). This can be accomplished
through volume control rotation or the pres-
scription can be modified. Skinner (1988)
suggested decreasing the saturation sound
pressure level (SSPL90) by 3 dB. Balfour and
found that listeners with cochlear pathology
showed 6 to 9 dB of loudness summation.
Although the binaural signals were per-
ceived as louder, they were not perceived as
uncomfortable, leading Hawkins and col-
leagues to suggest that a binaural hearing
aid fitting, on average, does not require a
special correction factor for SSPL90.

Chapter 1’s Table 1–1 identifies various
characteristics of prescriptive formulas. One
option that may be included in a prescriptive
formula is the ability to indicate that the audi-
ologist is pursuing binaural amplification.
The program then automatically reduces the
prescribed gain (across input levels and fre-
quencies) by some predetermined amount
(usually 3 to 6 dB). Ideally the prescriptive
data would be corrected and any verification
data (e.g., real-ear insertion gain or real-ear
aided response) would be corrected as well.
The user should have a clear understanding
of what is adjusted. For instance, the desired
sensation level fitting algorithm (Cornelisse
et al, 1995) does not provide corrected verification targets for a binaural fitting. Figure 7–4 provides an example of the National Acoustics Laboratories nonlinear version 1 (NAL-NL1) (Byrne et al, 2001) fitting algorithm when monaural fitting is selected. Figure 7–5 presents the same hearing loss, but with a binaural fitting selected. The coupler and real-ear aided gain targets are reduced for the binaural fitting. Some of the proprietary methods (algorithms associated with a particular manufacturer and technology) also provide a binaural correction to gain. For example, some manufacturers provide a scroll bar that allows the user to choose the desired level of correction for binaural summation and then automatically applies this to the program. This type of correction will be most important for individuals using automatic technology that removes the need for a volume control.

Lindley (2001) and Bentler and Pavlovic (1989) reported a greater amount of binaural loudness summation in subjects with hearing loss as opposed to subjects with normal hearing. In fact, the loudness summation patterns for comfortable and loud sounds were opposite that of the subjects with normal hearing. These different patterns of loudness summation between subjects with normal hearing and subjects with hearing loss violate an assumption of several fitting strategies. For example, the visual input-output locator algorithm (VIOLA; Cox and Flamme, 1998) prescribes amplification characteristics based on the assumption that loudness summation is identical between subjects with normal hearing and subjects with hearing loss. Until more data are available, the audiologist will have to rely on verification techniques to make adjustments for individual hearing aid users.

**Binaural Considerations in Verification**

Byrne (1981) suggested that it is probably unnecessary to document the advantage provided by binaural listening. The improvements in SNR that produce enhanced intelligibility are predictable from the physiological arrangements of the ears on the head. The head shadow is primarily present for high frequencies. Adequate high-frequency gain can be verified through standard real-ear probe microphone measurements (see Chapter 3 for a description of these measurements). There has been attention given to the finding that some individuals with moderate-to-severe high-frequency hearing loss do not benefit from audibility at these frequencies (Ching et al, 1998; Hogan and Turner, 1998). If distortion necessitates reducing audibility in the high frequencies, some binaural advantage will be lost.

Limitations in the reliability and sensitivity of word recognition tests limit their usefulness in demonstrating binaural advantage (Thornton and Raffin, 1978; Cox et al, 1981; Mueller et al, 1981; Danhauer et al, 1991). As discussed previously, newer tests of word recognition in noise (e.g., SIN, HINT) may be more useful in quantifying binaural benefit.

Cox and Alexander (1995), Cox and Rivera (1992), and Cox and Gilmore (1990) provide data related to using a subjective measure of hearing aid benefit. This type of questionnaire may be the most appropriate measure of perceived hearing aid benefit. A variety of items relate to binaural listening (noise, localization, etc.). If the questionnaire is used in a pre- and posttest arrangement, the clinician would expect improvement on the subscales related to binaural listening (e.g., background noise). The clinician may modify the fitting based on the results of the questionnaire.

Verification is always dependent on the original goals of the hearing aid fitting. If audibility at various input levels across frequencies was a goal, then real-ear probe microphone measures would be an appropriate verification technique. If the original goals were generated by a patient expectation worksheet (Palmer and Mormer, 1997) or the APHAB (Cox and Alexander, 1995), then a posttest using the same measure would be called for. If a return to normal loudness perception (where soft sounds, moderate
Figure 7-4. National Acoustic Laboratories nonlinear version 1 (NAL-NL1) prescriptive data for a moderate, sensorineural hearing loss. These data illustrate the prescription based on a monaural fitting.
Figure 7–5. NAL-NL1 prescriptive data for a moderate, sensorineural hearing loss. These data illustrate the prescription based on a binaural fitting. The gain targets are reduced as compared with the targets in Figure 7–4.
sounds, and loud sounds are perceived as soft, moderate, and loud through the hearing aid) was the goal, the audiologist may want to make sound-field measures of these perceptions. Palmer et al (2000) suggest a protocol for this type of measurement where the amplified user is compared with normally hearing individuals. The final measurement in this type of verification should be performed binaurally because that will be the person’s standard listening condition. This may be the best technique for determining what modifications are necessary based on the individual’s binaural loudness summation.

Libby (1981) argued that too much emphasis has been placed on clinical test procedures to demonstrate binaural advantage after a hearing aid fitting. Harford (1988) goes a step further and suggests that considering the available information concerning binaural benefit, perhaps the emphasis should be on justifying the use of only one hearing aid. Byrne (1981) agrees, indicating that considering the few cases in which a binaural fitting may be disadvantageous, it is preferable to fit all hearing aid users binaurally unless there is a specific audiologic or medical contraindication. This is especially important when considering the pediatric population. Children pose even more problems in terms of obtaining clinical measures of binaural benefit simply because of their age and inability to sit still. As reviewed in this chapter, binaural benefits are psychoacoustic phenomena related to having two ears separated in space and signals at varying azimuths. One can assume that a binaural hearing aid fitting will assist in meeting the five goals of a hearing aid fitting as long as sound has been made audible across a wide range of frequencies. This is an obtainable goal for individuals with moderate, bilateral, sensorineural hearing loss regardless of age.

Orientation/Follow-Up

For patients who remain unconvinced as to whether they want to pursue monaural or binaural amplification, Palmer and Mormer (1997) provided a hearing aid commentary that can be used to assign both a monaural and binaural configuration of hearing aid use over a several week period. This type of within-situation comparison may assist the individual in directly perceiving binaural advantages (Erdman and Sedge, 1981, 1986; Schreurs and Olsen, 1985).

Summary

Binaural listening directly impacts several of the goals for a hearing aid fitting. Audibility across frequencies without feedback is more easily achieved with binaural amplification. Less overall gain is required when two hearing aids are used (a reduction of 3 to 6 dB of gain generally is possible with binaural versus monaural amplification). Part of perceiving sound quality as adequate is perceiving a natural environment. Binaural hearing aid users experience sound around them in a more natural way than a monaurally aided individual. This is related to the individual’s ability to localize the direction from which sound is coming. This ability also impacts goal 4: creating a safe listening environment. Our ability to localize the direction of sound contributes directly to our ability to be safe in our environment and to our perception of being safe (feeling that we are oriented in space). Finally, when one defines the patient’s communication needs and expectations, it is very common to find that an individual needs to or wants to communicate well in noisy situations. It is the rare patient with moderate, bilateral, sensorineural hearing loss who comes into the clinic expressing only a need to hear well in quiet situations or expressing no current difficulty hearing in noise. This chapter outlined the need for binaural input into the auditory system to hear well in noise. The majority of individuals with bilateral, sensorineural hearing loss will benefit from binaural amplification across several of the goals for the hearing aid fitting. The individual with bilateral, sensorineural hearing loss who does not pursue binaural amplification should be carefully
counseled and the reasons for monaural amplification should be documented.

My 3-year-old son, Grant, summarized the issue of providing binaural amplification when he came to my office to visit and noticed a stuffed elephant on my shelf. This stuffed animal is wearing a hearing aid and is used to make young children more comfortable with the idea of having hearing aids. I had never thought about it, but the elephant has only one hearing aid. Grant asked, “Why does the elephant only have one hearing aid if he has two ears? Oh! Does he only have one hurt ear?” Something so obvious to a 3-year-old should be obvious to the rest of us. If a 3-year-old does not convince you, Robert Sweetow (1991) summed up the need for binaural hearing when he indicated that unless there is significant evidence contraindicating two instruments, binaural fitting should always be attempted. Sweetow went on to quote Noel Matkin as saying, “If God wanted us to have one ear, he would have placed it in the middle of our foreheads.” The need to hear with two ears is intuitive and is supported by a myriad of basic and applied research reviewed in this chapter. The majority of individuals with binaural, symmetrical, sensorineural hearing loss should be provided with well-fit, binaural hearing aids that will meet the goals of a hearing aid fitting, which include communication and safety.

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References


Appendix: Sample Hearing Aid Consent Form

I acknowledge that I have been provided with the following information regarding my hearing instrument fitting:

1. Information regarding the benefits of binaural versus monaural hearing instrument use
2. Information on the use of the “telephone” coil or direct audio input with my hearing instruments
3. Information on special hearing instrument circuitry or technology that may be appropriate for my hearing instrument fitting
4. Information on assistive listening and/or alerting devices necessary to maximize my communication ability and/or safety
5. Information on the operation, maintenance, and use of my hearing instrument(s)
6. Information regarding hearing instrument insurance programs and the manufacturer’s warranty on my instrument
7. Information on the Americans with Disabilities Act (ADA) and my rights under this law
8. Information regarding proper battery storage and the dangers of ingestion of hearing instrument batteries

(Patient’s Signature; Date)  (Dispenser’s Signature; Date)
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