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Adaptation to Loudness and Environmental Stimuli in Three Newly Fitted Hearing Aid Users

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Abstract

Hearing aid fitting strategies can be categorized according to whether a loudness normalization or a loudness equalization rationale is employed. Regardless of the underlying rationale, the amount of patient participation in determining the initial hearing aid settings will vary when an audiologist-driven (AD) versus a patient-driven protocol is employed. When an AD protocol is used, few changes are made during the initial fitting session based on user feedback. It is assumed that the patient will adapt to the loudness and/or sound quality provided by the hearing aids if not immediately acceptable. The following three case reports document varying degrees of adaptation to hearing aid settings derived using an AD approach. Clinical implications will be discussed.

Key Words: Adaptation, fitting protocols, hearing aids, sensorineural hearing loss

Abbreviations: AD = audiologist driven, DSL [i/o] = Desired Sensation Level input/output, EN = environmental noise subscale, HINT = Hearing in Noise Test, IHAFF = Independent Hearing Aid Fitting Forum, LE = loudness equalization, LN = loudness normalization, PD = patient driven, PHAP = Profile of Hearing Aid Performance, RAB = Ricketts and Bentler, SII = Speech Intelligibility Index, WDRC = wide dynamic range compression

Audiologists typically employ some type of fitting strategy when determining initial hearing aid settings for a given individual with hearing loss. The underlying theoretical goals of most strategies designed for fitting wide dynamic range compression (WDRC) hearing aids can be placed into one of two categories (Table 1) (Lindley, 1999). Fitting strategies that incorporate a loudness normalization (LN) rationale attempt to prescribe amplification characteristics that should restore normal loudness perception not only for overall speech levels but also for individual speech elements within the speech signal (e.g., amplitude relationship between vowels and consonants). Examples of fitting strategies incorporating this rationale include FIG6 (Gitles and Niquette, 1995), the Independent Hearing Aid Fitting Forum (IHAFF) (Valente and Van Vliet, 1997), and Desired Sensation Level input/output (DSL [i/o]) (Cornelisse et al, 1995) when a variable compression ratio is chosen.

The remaining fitting strategies incorporate a rationale best described as loudness equalization (LE). The typical goals with these strategies are to normalize loudness perception for overall speech levels and equalize loudness for individual speech elements within the speech signal at a given overall level (i.e., vowels and consonants are presented at an equal intensity). Examples of fitting strategies that could be placed in this category include DSL[i/o] (Cornelisse et al, 1995) when a fixed compression ratio is chosen and National Acoustics Laboratories-Non-Linear 1 (NAL-NL1) (Dillon, 1999).

Regardless of the underlying rationale, the patient's role in determining initial amplification characteristics will vary according to how the

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Table 1 Suggested Conceptual Framework for Categorizing Fitting Strategies Based on Underlying Theory and Incorporation into a Fitting Protocol

Underlying Theory *Fitting Protocol*	*Loudness Normalization*	*Loudness Equalization*
Patient driven	Loudness-based, individual-specific data employed in an attempt to restore normal loudness perception. Example = IHAFF protocol	Intelligibility-based, individual-specific data used in an attempt to present low- and high-frequency regions at equal intensity. Example = DSL[i/o], linear compression mode, LDLs entered
Audiologist driven	Loudness-based, average-data-employed, limited changes based on initial user perception. Example = FIG6	Intelligibility-based, average-data-employed in an attempt to present low- and high-frequency regions at equal intensity. Example = NAL-NL1

fitting strategy is incorporated into the overall fitting protocol. At one extreme, the hearing aids may be adjusted to match prescribed targets that are based solely on threshold data. Few, if any, changes are made based on initial feedback provided by the newly fitted individual. This approach assumes that the prescriptive target chosen by the audiologist will yield the highest aided performance and that the individual will eventually adapt to the loudness and sound quality provided by the hearing aids if not immediately acceptable. This audiologist-driven (AD) approach has the advantage of not requiring individual-specific measures of loudness perception and/or sound quality.

Conversely, the audiologist may choose to employ feedback provided by the individual in determining amplification characteristics. This patient-driven (PD) approach assumes that fittings based on individual-specific suprathreshold data will yield a more successful fitting in the form of higher user acceptance and sound quality as well as less need for additional adjustments postfitting. Individual-specific data are usually obtained at two stages of the fitting process. In stage one, audiometric information such as loudness contours or loudness discomfort levels are obtained when deriving appropriate targets. In stage two, loudness judgments for speech and/or warble tone stimuli are obtained on the day of the fitting, in the sound field, with the individual wearing the hearing aids. This information is typically employed to verify that the original fitting goals have been met.

Research has shown that hearing aid prescriptions derived using average-based data yield higher predicted speech intelligibility (Ricketts, 1996; Stelmachowicz et al, 1998). Ricketts (1996), for example, has used the Speech Intelligibility Index (SII) to predict the relative speech intelligibility provided by several fitting strategies including several designed for WDRC hearing aids. For two of these strategies (FIG6, DSL[i/o]), targets were generated from threshold data alone. For the remaining strategies (IHAFF, Ricketts and Bentler [RAB]), individual-specific measures of loudness growth were employed to determine a prescription.

Averaged SII predictions across speech inputs showed that the calculated SII was significantly lower in noise for RAB and IHAFF versus DSL[i/o] and FIG6 in noise. In quiet, RAB demonstrated significantly lower SII scores as compared with DSL[i/o]. The "cost" associated with this higher predicted intelligibility, however, is a prescribed frequency response that is significantly louder than those prescribed by the PD prescriptions.

Assuming that an AD fitting protocol is employed, and changes are not made to the prescribed settings, there would be support for employing fitting strategies that are threshold based as these theoretically result in the benefit of increased intelligibility. This support, however, is based on the assumptions that the predicted benefit in speech intelligibility is actually realized by the hearing aid wearer and that the individual can eventually adapt to a prescription that may initially be objectionable with regard to loudness and/or sound quality.

There have been studies that suggest that hearing aid wearers can and do adjust to the sound quality provided by their hearing aids (Ovegard et al; 1997; Palmer, 1997). Research conducted in the area of preferred hearing aid use gain, however, suggests that many individuals will not choose higher volume settings over time as experience with the hearing aid increases

(Berger and Hagberg, 1982; Bentler et al, 1993; Horwitz and Turner, 1997). If this is true, then the use of an AD protocol would be contraindicated as the hearing aid wearer would likely reject amplification and/or use the hearing aids at a lower volume setting (if able to adjust) than prescribed.

The following three cases document adaptation (or lack of adaptation) to the sound quality and loudness provided by hearing aids fitted using an AD protocol over a 2-month period. These individuals were part of a larger study with two main goals: (1) to document the relative aided speech recognition ability and sound quality provided by hearing aids adjusted according to an AD versus a PD fitting protocol and (2) to determine if individuals adapt to the sound quality and loudness provided by hearing aids adjusted according to an AD protocol.

The participants were new hearing aid users and were fit with Siemens two-channel, WDRC Music hearing aids without volume controls. The hearing aids were initially adjusted according to a DSL[i/o] prescription with only threshold data input. Adjustments were made on the day of the fitting only if the participant rated warble tones or speech presented at a comfortable level as uncomfortably loud. For each patient, loudness ratings and Profile of Hearing Aid Performance (PHAP) subscale scores for environmental noise (EN) over time are presented. The EN subscale deals with issues concerning aversiveness and distortion of sounds. In addition, Hearing in Noise Test (HINT) scores and sound quality ratings obtained by the individuals during the initial fitting session with the hearing aids adjusted according to an AD versus a PD protocol are provided (Nilsson et al, 1994). Speech, noise, and warble tone stimuli were presented at 0° azimuth. In all three cases, the frequency responses derived using the AD versus the PD protocol differed in the amount of low- and/or high-frequency gain prescribed.

CASE REPORTS

Patient A

Patient A was a 71-year-old male with a mild-to-moderately severe, sloping sensorineural hearing loss (see Figure 1 for audiometric data). The signal-to-noise ratio at which an individual correctly repeats the stimuli with 50 percent accuracy is the metric of measurement with the HINT. With the hearing aids adjusted according to the AD versus the PD protocol, HINT scores of −1.53 dB and 0.83 dB (difference = 2.36) were obtained, respectively. This 2.36 difference exceeds the 1.20 95 percent confidence limit provided in the HINT test manual when noise is presented at 0° azimuth. Thus, performance was significantly better using the AD prescription. The average sound quality rating for connected discourse presented in quiet at 65 and 75 dB SPL was 74 percent for the AD prescription and 63 percent for the PD prescription, resulting in a difference of 11.25 percent.

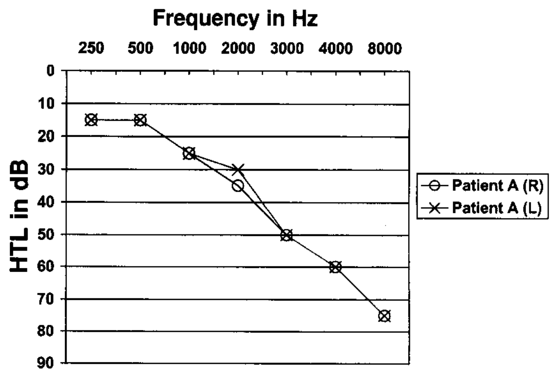

Figure 1 Audiogram for patient A. R = right, L = left.

Figure 2 provides the mean aided loudness ratings provided by patient A for warble tones at 500 and 3000 Hz during the initial session and at 1 and 2 months postfitting. The stimuli were collapsed between ears and among loudness categories into soft (S), comfortable (C), and loud (L) groups. Palmer and Lindley (1998) have shown that test–retest results fall within ± 10 dB on the Contour Test of Loudness Perception when administered to individuals with hearing loss (Cox, 1997). For patient A, the greatest difference, although not significant, is seen with the loud, 300-Hz warble tone stimuli

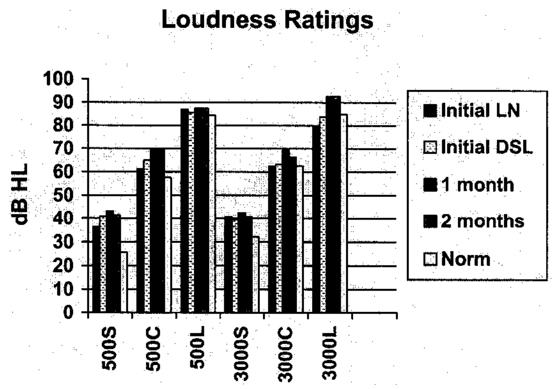

Figure 2 Loudness ratings for patient A. LN = loudness normalization, DSL = desired sensation level, C = comfortable, L = loud, S = soft.

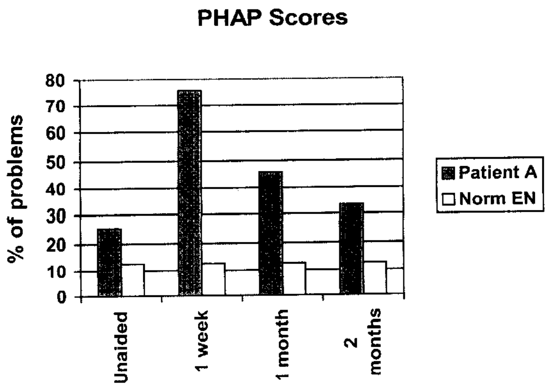

Figure 3 Environmental noise (EN) subscale scores on the Profile of Hearing Aid Performance for patient A.

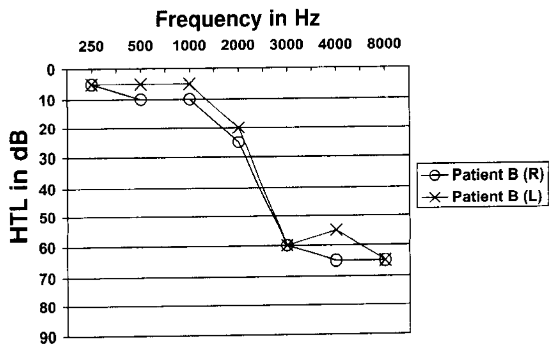

Figure 4 Audiogram for patient B. R = right, L = left.

(3000 L) where a 9-dB louder signal during session three would be needed to elicit the same rating obtained during session one. If adaptation to loudness were to occur, one would expect to see this adaptation with the high-frequency stimuli as this is where patient A's hearing loss, and the need for amplification, is greatest.

Figure 3 provides the EN subscale scores produced by patient A when unaided and at 1 week, 1 month, and 2 months postfitting. Mean percentage of problem scores reported by 40 individuals with normal hearing are also provided for comparison. The percentage of problems is highest at 1 week postfitting. By 2 months postfitting, the percentage of problems indicated is approaching the level seen when unaided.

Anecdotally, this individual reported less problems with the loudness of sounds throughout the 2-month period. No adjustments were required postparticipation in the study, and the patient continues to use amplification.

Patient B

Patient B is a 47-year-old man with a mild-to-moderately severe sloping high-frequency sensorineural hearing loss. His audiometric data are presented in Figure 4. Patient B's HINT scores were –4.12 dB and –5.06 dB for the AD and LN settings, respectively. This difference (0.94) is not clinically significant. Sound quality ratings were identical between conditions and were relatively low (49%). Figures 5 and 6 provide patient B's loudness rating and EN subscale data.

It is evident that patient B is not showing adaptation (i.e., height of the bars are not rising as a function of time), especially with the high-frequency stimuli. His ratings are still well below normal, meaning that he continues to

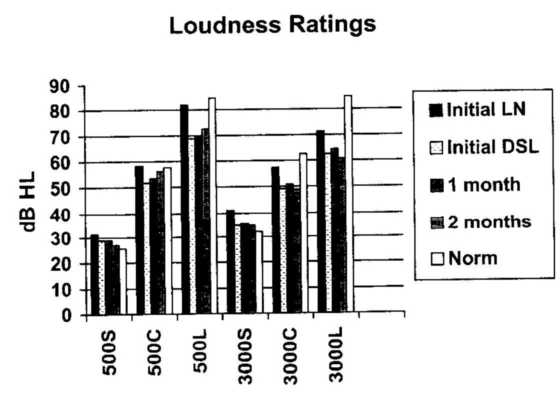

Figure 5 Loudness ratings for patient B. Reprinted from *The Hearing Journal*, November 1999 (Volume 52, number 11), by permission of the publisher, Lippincott Williams & Wilkins. LN = loudness normalization, DSL = Desired Sensation Level, C = comfortable, L = loud, S = soft.

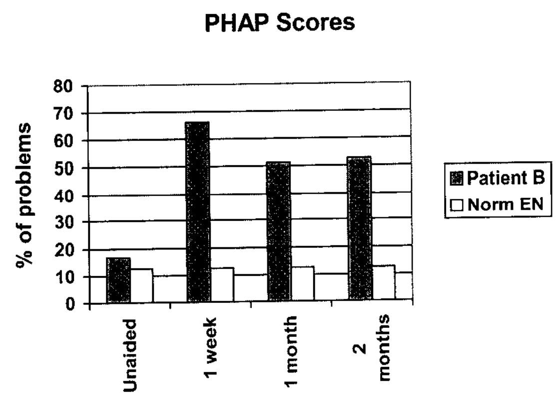

Figure 6 Environmental noise (EN) subscale scores on the Profile of Hearing Aid Performance for patient B. Reprinted from *The Hearing Journal*, November 1999 (Volume 52, number 11), by permission of the publisher, Lippincott Williams & Wilkins.

perceive the stimuli as too loud at the 2-month visit. In support of the loudness rating data, patient B demonstrates a fairly high percentage of problem scores on the EN subscale, peaking at 1 week postfitting but still much higher than normal at 2 months postfitting.

Patient B reported problems with loudness, especially for high-frequency stimuli (e.g., running water) throughout the 2-month period. Postparticipation in the study, high-frequency gain was reduced (the compression ratio was 4:1 in the high frequencies) in an attempt to address this problem. However, patient B ultimately returned the hearing aids reporting no significant benefit. This report was substantiated by his aided PHAP scores on the remaining subscales.

Patient C

Patient C was a 64-year-old female with a mild-to-moderate gently sloping sensorineural hearing loss (Fig. 7). HINT scores were 0.12 dB and –0.71 dB with the AD versus the PD settings, respectively. This did not represent a clinically significant difference. Sound quality ratings were similar between the AD and the PD settings (84% and 87%, respectively).

Figures 8 and 9 show patient C's loudness ratings and EN subscale scores over the 2-month period. Patient C's loudness ratings for the low-frequency stimuli are initially higher than those provided by individuals with normal hearing, indicating that the patient could tolerate louder sounds than the individuals with normal hearing. There is a significant (18 dB for the 500-Hz, loud stimuli) decrease in loudness ratings over the 2-month period (i.e., signal levels required to elicit a given rating were lower than during the initial session). By the 2-month visit, loudness ratings are lower than those provided by the individuals with normal hearing. This "reverse" adaptation is seen to a smaller, less

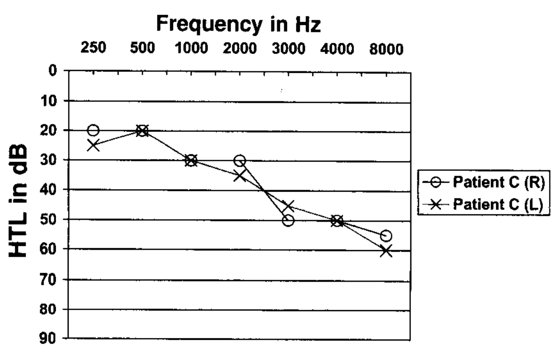

Figure 7 Audiogram for patient C. R = right, L = left.

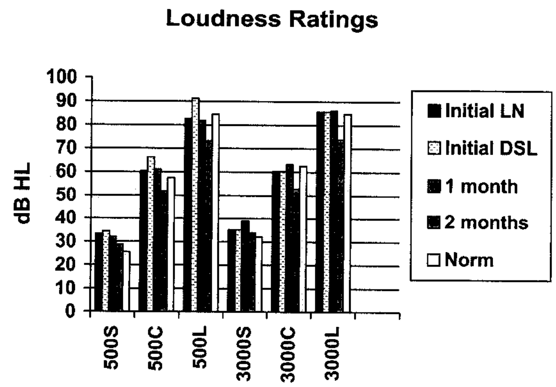

Figure 8 Loudness ratings for patient C. LN = loudness normalization, DSL = Desired Sensation Level, C = comfortable, L = loud, S = soft.

systematic extent with the 3000-Hz stimulus. The EN subscale scores remained relatively constant throughout the 2-month period remaining close to the unaided score.

Anecdotally, patient C reported few problems related to aided loudness or sound quality with the exception of some predominantly lower frequency noises (e.g., air conditioner fan). Patient C reported significant benefit from the hearing aids and only required a small decrease in low-frequency gain postinvolvement in the study.

COMMENTS

It is evident from the above three case reports that not all individuals with hearing loss will adapt in an identical manner to the loudness and/or sound quality provided by hearing aids. At this point, one can only speculate as to the variables that determine why some individuals adapt more so than others. Clinically, it would be useful to know these variables a priori as

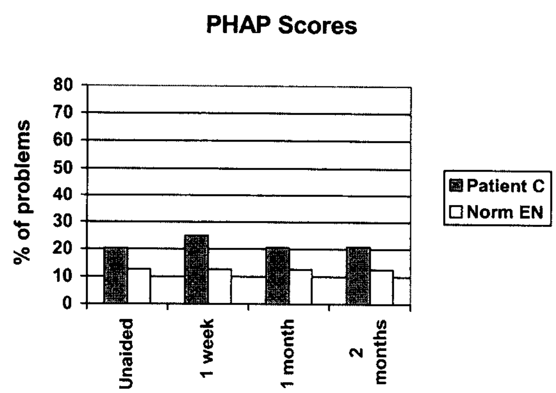

Figure 9 Environmental noise (EN) subscale scores on the Profile of Hearing Aid Performance for patient C.

this would aid in determining appropriate and realistic hearing aid settings for a given individual.

Degree and configuration of hearing loss likely play a role in determining the potential for adaptation. Of the 18 participants in the larger study, the individual who demonstrated the greatest and most systematic amount of adaptation had a mild-to-moderate (thresholds < 60 dB HL), relatively flat sensorineural hearing loss (Lindley, 1999b). Many of the participants who demonstrated little to no adaptation had moderate-to-moderately severe high-frequency (> 2000 Hz) sensorineural hearing loss. Recent work by Hogan and Turner (1998) suggests that these individuals may not receive benefit from amplification to regions with moderate high-frequency loss. Indeed, in addition to problems with loudness, these individuals sometimes reported that the sound quality was relatively poor with the hearing aids. Perhaps the extent of damage to the cochlea precludes any potential for adaptation. Other factors that may contribute include age and gender of the individual, motivation for hearing aid use, personality, and how far from normal loudness perception they function initially using hearing aids adjusted according to an AD protocol.

The method in which the AD protocol was implemented may have affected the potential for adaptation. In these cases, the hearing aids were adjusted to meet the AD prescription (DSL [i/o]) from the beginning. An alternative route would be to adjust the hearing aids using a PD approach that yields a response that is immediately acceptable to the individual. Over time, the output could be gradually increased until the patient will not tolerate more increases or until the AD prescription is realized. Indeed, some manufacturers (e.g., Adaptation Manager from Oticon, Inc, Somerset, NJ) have included mechanisms in their fitting software to gradually introduce amplification to individuals newly fitted with hearing aids, recognizing the possibility that prescribed settings may not be initially acceptable.

Finally, the correlation, or lack of correlation, between loudness ratings obtained in the clinic and subjective evaluation of real-world performance needs to be investigated. For some participants, there is a correlation between clinic data and real-world functioning. As loudness ratings improved, percentage of problem scores on the EN subscale of the PHAP decreased. For others, loudness ratings were almost identical to those provided by individuals with normal hearing. Yet these individuals still demonstrated significant problems with regard to the loudness and sound quality of real-world stimuli. One possible explanation for this finding is the variance in loudness summation demonstrated by the subjects. The relative difference in loudness ratings for narrow-band stimuli (e.g., warble tones) and broadband stimuli (e.g., speech) was not constant among the subjects.

CLINICAL SUGGESTION BASED ON THESE FINDINGS

It is impossible at this point to recommend specific guidelines in determining when and with whom an AD protocol versus a PD protocol should be employed. Undoubtedly, there is a subgroup of individuals who will likely tolerate and learn to accept any reasonable frequency response provided. At the other extreme are individuals who will only accept a frequency response that is immediately tolerable, regardless of speech intelligibility ramifications, and will never demonstrate adaptation. The majority of individuals fitted with hearing aids likely fall somewhere between these two extremes.

These findings do support the use of fitting software that gradually introduces amplification as a function of hearing aid experience. Since it is difficult to predict who will and who will not demonstrate adaptation, a reasonable compromise would be to start with a setting that is immediately acceptable. Over time, the amount of amplification can be gradually increased, if applicable, until a frequency response that is satisfactory to both the patient and the audiologist is reached.

Many of the individuals in this study reported that provision of a hearing aid wearing schedule was useful and helped to minimize initial adjustment difficulty (Palmer and Mormer, 1996). Using this schedule, patients wear the hearing aids 2 to 4 hours on the first day in relatively quiet environments. Over the next 8 days, use time is systematically increased, and the individual is encouraged to use the hearing aids in increasingly difficult environments. By providing the patient with a wearing schedule, the patient is reassured that immediate acceptance is unlikely and that the fitting of hearing aids is a process, rather than a single event.

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