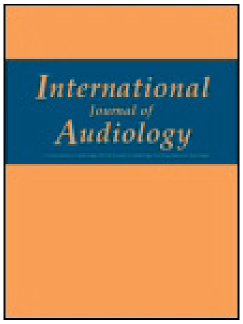

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Variation in preferred gain with experience for hearing-aid users

Key Words

Gain adaptation
Acclimatization
Gain preference
Hearing aid
Amplification
Experience
Loudness

Abbreviations

4FA: Four-frequency-average
ABR: Auditory brainstem response
BTE: Behind-the-ear
DLI: Discrimination limen for intensity
DSL[i/o]: Desired sensation level (input/output)
EN: Environmental noise
FAAF: Four-alternative auditory feature
FF: Free field
HA: Hearing aid
HFA: High-frequency average
HFC: High-frequency cut
HL: Hearing level
HTL: Hearing threshold level
ITC: In-the-canal
ITE: In-the-ear
LFA: Low-frequency average
LFC: Low-frequency cut
NAL: National Acoustic Laboratories
NAL-NL1: National Acoustic Laboratories non-linear version 1
NAL-R: National Acoustic Laboratories revised
PHAP: Profile of hearing-aid performance
REIG: Real-ear insertion gain
SD: Standard deviation
SE: Standard error
SLM: Sound-level meter
SPL: Sound pressure level

Abstract

This study aimed to determine whether gain adaptation occurs, and at which frequency bands, among new hearing aid (HA) users. Fifty new and 26 experienced HA users were fitted with three listening programs (NAL-NL1 and NAL-NL1 with low- and high-frequency cuts) in the same hearing instrument family. Real-life gain preferences and comfortable loudness levels were measured one, four, and 13 months post-fitting for the new HA users, and one month post-fitting for the experienced HA users. Relative to experienced HA users, new HA users preferred progressively less overall gain than prescribed as the hearing loss became more severe. Gain adaptation occurred in new HA users with greater hearing loss, but was not complete 13 months post-fitting, and was not explained by changes in loudness perception. Preferences for a high-frequency gain cut by half of all study participants could not be predicted from audiological data. Gain adaptation management is recommended for new HA users with more than a mild hearing loss.

Sumario

El propósito del estudio fue determinar si es que ocurre la adaptación a la ganancia y en cuáles bandas de frecuencia, entre usuarios nuevos de un auxiliar auditivo (HA). Cincuenta nuevos usuarios de HA y 26 con experiencia fueron adaptados con tres programas diferentes (NAL, NL1 y NAL-NL1 con cortes de frecuencia altos y bajos) con aparatos de la misma familia. Se midieron las preferencias de ganancia en la vida real y los niveles de confortabilidad a los cuatro y a los 13 meses después de la adaptación en los nuevos usuarios de HA y un mes después de la adaptación en los usuarios experimentados. Con respecto a los usuarios experimentados, los nuevos usuarios prefirieron progresivamente una ganancia menor que la prescrita conforme la hipoacusia era más severa. La adaptación a la ganancia ocurrió en los nuevos usuarios de HA con mayor hipoacusia, pero aun no era completa a los 13 meses después de la adaptación y no se explicaba a partir de los cambios en la percepción de la intensidad. No fue posible predecir a partir de los datos audiológicos, la preferencia por un corte de alta frecuencia que tuvieron la mitad de los participantes del estudio. El manejo de la adaptación de la ganancia es recomendado para nuevos usuarios de HA con una pérdida auditiva mayor a la hipoacusia leve.

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VAD: Voice activity detection
VC: Volume control
WDRC: Wide dynamic range compression

According to clinical anecdotes, new hearing aid (HA) users prefer less gain than experienced HA users (e.g. Mueller & Powers, 2001; Convery et al, 2005). If this is true, the implication is that new HA users will prefer gradually increasing gain after fitting. The notion appears plausible given that the onset of a hearing loss in many adults happens gradually over time, hence the unaided hearing-impaired person has become accustomed to listening to surrounding sounds at softer levels than normal. When first fitted with a hearing aid, the new user may therefore need time to adapt to the higher output levels presented by the device.

In response to the belief that new HA users need time to adapt to prescribed gain levels, gain adaptation tools have been implemented in some hearing-aid manufacturers' fitting software. Such tools allow the clinician to select reduced gain levels relative to a target before the fitting is verified and validated (e.g. Eberwein et al, 2001; Schum, 2001). Over time, the clinician will then increase gain in a gradual fashion until the target is reached. More recently, hearing devices have been introduced that contain a feature that will automatically increase gain over a predetermined period of time (e.g. Robinson & Verberne, 2003; Schum & Beck, 2006).

A literature review by Convery et al (2005) on gain preference by new and experienced HA users over time, however, found very little support for gain adaptation in new HA users. Specifically, data from three studies (Cox & Alexander, 1992; Horwitz & Turner, 1997; Humes et al, 2002), that provided gain preferences relative to the NAL-R prescription (Byrne & Dillon, 1986) for a total of 98 new and 77 experienced HA users, suggested that the average difference in preferred gain between new and experienced users was no more than 2 dB, with new users preferring less gain than experienced users. This difference was not statistically significant, nor did it appear to change over a period of up to 12 months. The trend for new users to prefer slightly less gain than experienced HA users was also found by Byrne & Cotton (1988) and Marriage et al (2004), both of whom investigated the acceptance of prescribed gain among new and experienced HA users. In Marriage et al (2004), the 2.6 dB lower gain required by new users relative to experienced users to accept the hearing-aid fitting was statistically significant. However, it should be noted that adjustments to the hearing-aid settings were restricted to those necessary for the participants to accept, rather than prefer, the fitting. It should also be noted that the observed differences in gain preferred by new and experienced HA users in the above studies are smaller than the typical gain reductions of 5–10 dB introduced in the adaptation managers implemented in various fitting software. More recently, a study by Smeds et al (2006a, 2006b) compared loudness perception and gain preferences of normal-hearing listeners and new and experienced HA users in the laboratory and in the field. The study found no significant difference in loudness ratings or gain preferences between new and experienced HA users.

While the literature on the gain preferred by new and experienced HA users shows inconsistent support for gain adaptation in new HA users, there are strong suggestions that some changes do happen in the auditory system as a result of wearing hearing aids. Such changes may be referred to as acclimatization, of which gain adaptation is one aspect. The mechanism of acclimatization may be explained by neural plasticity (i.e. a reorganization of the neural maps following damage at the peripheral level) in the auditory system. Auditory plasticity may occur as a result of the hearing loss, and again through rehabilitation with hearing aids when acoustic cues that were lost through the acquired hearing loss are reintroduced. This theory is based on numerous studies that have demonstrated that the representation of acoustic stimuli along the auditory pathway can be remodelled by various hearing experiences in both animals and humans (e.g. Palmer et al, 1998; Philibert et al, 2005; Willott, 1996).

Auditory acclimatization as a result of hearing-aid usage has been discussed widely in the literature since Gatehouse (1989) reported that unilaterally-fitted listeners, with symmetric bilateral hearing loss, performed better in a word recognition task with their aided ear (tested unaided) at a high intensity level (95 dB SPL), and performed better with their unaided ear at a lower intensity level (65 dB SPL). Subsequently, the acclimatization effect after hearing-aid fitting has been studied by means of changes in (1) speech recognition performance over time (e.g. Bentler et al, 1993a; Cox et al, 1996; Gatehouse, 1992, 1993; Munro & Lutman, 2003; Reber & Kompis, 2005; Saunders & Cienkowski, 1997; Silman et al, 1993); (2) subjective ratings of benefit or sound quality over time (e.g. Bentler et al, 1993b; Ovegard et al, 1997); (3) rated loudness perception or intensity discrimination over time (e.g. Olsen et al, 1999; Philibert et al, 2002; Philibert et al, 2005; Robinson & Gatehouse, 1995, 1996); or (4) a combination of some of the above measures (Amorim & Almeida, 2007; Cox & Alexander, 1992; Horwitz & Turner, 1997; Humes & Wilson, 2003; Humes et al, 2002; Lindley et al, 2000; Prates & Iorio, 2006; Yund et al, 2006). Excellent reviews of the literature published before 1998 that presented inconsistent conclusions, presumably due to procedural variations, are found in Turner et al (1996) and Palmer et al (1998). Among the post-1998 literature, the findings continue to be inconsistent. However, across all the literature acclimatization appears to be more evident in objective than subjective measurements of benefit. Further, the more recent studies that show evidence of acclimatization seem to lend support to a theory that acclimatization to high-level, high-frequency sounds may occur after fitting with hearing aids.

For example, Munro and Lutman (2003) obtained speech recognition scores from 16 unilaterally fitted, first-time HA users at zero, six, and 12 weeks post-fitting. At each test, speech scores were obtained aided and unaided for both ears using three presentation levels of speech (55, 62, and 69 dB SPL), and a benefit score was calculated by subtracting the unaided score from the aided score. There was a significant improvement in benefit score over time for the highest presentation level and for the fitted ear that resulted from improved aided scores. It is noted that the four-alternative auditory feature (FAAF) test (Foster & Haggard, 1987) that was used in this study is particularly sensitive to high-frequency auditory capabilities. In Olsen et al (1999), a categorical loudness scaling test was administered to 18 full-time HA users (eight fitted unilaterally and 10 fitted bilaterally) and 18 non-users. The test was administered for each ear unaided at four frequencies (0.5, 1, 2, and 4 kHz). However, for each listener, only the response for one ear and frequency was included in the analysis. The main criterion for inclusion in the analysis was that the hearing loss was in the range of 50 to 75 dB HL for that frequency. Another aim was to balance the frequencies included across the two listener groups. A majority of data (75%) included in the analysis was measured at the two higher frequencies (2 and 4 kHz) and showed that the mean level rated 'loud' was significantly higher (by 4.5 dB) for the HA users than for the non-users. Data were incomplete for the 'very loud' category, but the available data showed the same tendency as the data for the 'loud' category. Data for softer loudness categories showed no significant differences between groups. Similar results were observed by Philibert and colleagues (Philibert et al, 2002, 2005). In both studies, listeners completed a categorical loudness scaling test and a discrimination limen for intensity (DLI) test using 0.5 and 2 kHz tones. The DLI test was performed at two intensity levels (75 and 95 dB SPL). In the 2002 study, the performance by nine long-term bilateral HA users was compared to that of nine non-users. The two listener groups were balanced for age, gender, and hearing thresholds. Non-users assigned lower intensity levels to the same loudness categories than did long-term HA users and showed poorer DLI performance. However, significant differences between groups were only found for the loudness perception task at 2 kHz and the differences were more prominent for the category 'OK' and louder. In the 2005 study, eight new bilaterally fitted HA users were tested at one, three, and six months post-fitting. The authors found changes in loudness perception over time for the highest level and highest frequency. In addition, the auditory brainstem responses (ABRs) were measured on the eight participants in the 2005 study, and over time there was a shortening of the wave V latency in the right ear, suggesting that a peripheral auditory system modification was induced by the hearing aid. According to Yund et al (2006), acclimatization is more likely in new HA users after fitting with multichannel wide dynamic range compression (WDRC) than linear amplification. Over a period of 32 weeks, new HA users fitted with WDRC showed a significant improvement in benefit scores obtained with a nonsense syllable test whether tested with WDRC or linear amplification, while new HA users fitted with linear amplification showed no change in benefit with either signal processing strategy relative to unaided performance. After 32 weeks, the two listener groups switched signal processing strategies. Although there was a small but significant improvement in aided performance from week 32 to week 40 for both listener groups, the magnitude of the improvements was much smaller than that seen for the initial WDRC experience. The authors suggest that the difference in performance is caused by multichannel WDRC processing more effectively bringing the range of speech frequencies and intensities into the reduced dynamic range of the impaired ear.

In contrast, an investigation of the acclimatization effect in twenty-three first-time HA users who were bilaterally fitted using one of three different fitting protocols found an improvement over time in both unaided and aided speech recognition scores for a presentation level of 50 dB SPL (Reber & Kompis, 2005). Interpretation of data obtained at two higher presentation levels (65 and 80 dB SPL) were complicated by ceiling effects in both the aided and unaided data. Data were collected at zero weeks, two weeks, and six months post-fitting, during which time there was little variation in the listeners' selected insertion gain. A training effect was also ruled out by the authors because the improvement was greater in the aided than in the unaided condition. Three case reports presented by Lindley et al (2000) demonstrated different levels of acclimatization to hearing-aid settings according to categorical loudness ratings and profile of hearing-aid performance (PHAP) subscale scores for environmental noise (EN) measured over a two-month period. While the participant who demonstrated the greatest and most systematic amount of acclimatization (i.e. the need for a louder level to reach the same loudness category and the demonstration of reduced handicap over time) had a mild to moderate, flat hearing loss, many of the participants who demonstrated little or no acclimatization had moderate to moderately severe high-frequency hearing loss (>2 kHz). Finally, in a longitudinal study (Humes et al, 2002; Humes & Wilson, 2003), little evidence for acclimatization was found in bilaterally fitted HA users based on subjective and objective measurements of benefit obtained from outcome measures and speech recognition scores after one, two, and three years of hearing-aid usage. The trend for acclimatization, however, varied greatly among individual participants.

The studies that have found evidence for acclimatization suggest that hearing-aid fitting may induce functional plasticity in the auditory system. One explanation for the varied outcomes may be the extent to which plasticity occurs in the individual and how quickly it occurs. For example, it has been speculated that neural plasticity in the auditory system is more likely to happen when the hearing loss is severe. This is because individuals with severe hearing loss are more likely to miss out on some acoustic information, such as portions of the speech signal, that is reintroduced when fitted with a hearing aid (Palmer et al, 1998). Speech recognition measurements obtained over time for listeners with severe or profound hearing loss after they switched from linear to non-linear amplification support this hypothesis (Flynn et al, 2004; Kuk et al, 2003).

Overall, the issue of auditory acclimatization in hearing-aid rehabilitation has not been completely resolved. In terms of the overall negative outcome of past studies on the gain preferred by new and experienced HA users, it was noted by Convery et al (2005) that interpretation of the existing data was somewhat complicated. First, all but one of the reviewed studies did not directly aim to investigate the issue of gain adaptation in new HA users, and therefore the measured gain preferences were not well controlled for such confounding factors as degree of hearing loss and prescriptive target. Second, procedures differed greatly across the reviewed studies. In particular, the definition of 'new' and 'experienced' HA users and the goal of the fitting rationale varied. The use of different types of hearing aids within and across studies and the different audiological profiles of new and experienced HA users may also have had an effect on the findings. Convery et al (2005) therefore suggested that there was still a need for future studies that more specifically addressed the question about gain adaptation in new HA users, and that better controlled all relevant parameters. Further, gain preferences were often measured in terms of changes made to overall gain while data on auditory acclimatization suggest that the effect may be limited to high-frequency sounds.

The aim of this study was to investigate gain preferences overall and across the low and high frequencies over time in a large clinical population of new HA users. All participants were fitted with hearing aids from the same family. The hearing aids contained three listening programs: the NAL-NL1 prescription (Dillon, 1999), the NAL-NL1 prescription with a high-frequency cut, and, where possible, the NAL-NL1 prescription with a low-frequency cut. Gain preferences in everyday listening situations were monitored about one month, four months, and 13 months post-fitting. At these appointments, loudness perception was also measured. A control group comprising HA users with at least three years of experience with amplification was fitted with the same test device with the same three programs. The control group was subjected to the same test battery one month post-fitting. These data served as a reference for the measurements obtained from the new HA users over time. The specific research questions addressed were:

1. Do gain preferences for medium intensity levels of new and experienced HA users differ overall (averaged across 0.5, 1, 2, and 4 kHz), or only in the low (averaged across 0.25, 0.5, and 1 kHz), or the high (averaged across 2, 3, and 4 kHz) frequencies?
2. If gain preferences for medium intensity levels differ between new and experienced HA users, at what time post-fitting do the gain preferences of these groups converge?
3. If preferred gain does change post-fitting, is it related to changes in perceived loudness?

The study also addressed how the preferred gain levels for medium intensity levels compare with the NAL-NL1 prescription.

Methodology

Participants

New HA users were recruited and tested at 13 hearing centres from the Australian Hearing network (government subsidized clients) and at the National Acoustic Laboratories (NAL), while all experienced HA users were recruited and tested at NAL. Experience was defined as consistent hearing-aid usage (at least four hours a day) for at least three years. One new HA user (NA02) had worn amplification for three years as a child, but not for 27 years prior to recruitment for this study. Another two new HA users briefly wore amplification 10 years prior to recruitment. One of these participants (NA05) stopped using the hearing aid following a tympanoplasty, and the other (NA07) stopped using hearing aids due to problems in background noise. In all, 76 new HA users were recruited. Nineteen of these withdrew before the first test appointment after fitting, and three did not attend the final test appointment scheduled 13 months later. Reasons for withdrawal in the early stages of the study included dissatisfaction with amplification, poor health, and management problems. A further four new HA users were discarded from the data analysis. One of these participants had the test settings programmed in different orders in each ear, while another was fitted with unacceptably low gain relative to the prescribed target. The last two participants displayed shifts in the average threshold data measured across 0.5, 1, 2, and 4 kHz of 10 dB, including a shift of 20 dB at a single frequency, between test appointments. All 26 recruited participants with hearing-aid experience completed the study.

Table 1 shows an overview of the general profile of the two participant groups. The four-frequency-average (4FA) hearing threshold level (HTL) was measured across 0.5, 1, 2, and 4 kHz; the low-frequency-average (LFA) HTL was measured across 0.25, 0.5, and 1 kHz; and the high-frequency-average (HFA) HTL was measured across 2, 3, and 4 kHz. The slope was calculated as the difference between the HFA and LFA HTL. Only data from the fitted ear are reported for unilaterally fitted participants. For bilaterally fitted participants, data were averaged across ears. It is apparent from Table 1 that, on average, the range of hearing loss was milder among the new than among the experienced HA users. Although the aim was to match the audiometric profile between the two participant groups, it proved too difficult to find experienced HA users with mild hearing loss similar to some of the new HA users. The distribution of participants in the two groups across degree and configuration of hearing loss is shown in Table 2. Specifically, new users had milder, flatter hearing loss than experienced HA users, and more experienced users had steeply sloping hearing loss. Apart from two new HA users (IP02, NA05) who displayed a mixed hearing loss, all the participants had a sensorineural hearing loss.

There was a notable difference in the male/female ratio and age between the two groups; the experienced HA user group

Table 1. An overview of the general profile of the study participants.

Parameter	*New users (N = 50)*	*Experienced users (N = 26)*
Average experience with amplification (years) and range	0	11.2 [3.5, 26]
Male/female ratio (%)	50/50	73/27
Average age (years) and range	70.3 [33, 87]	74.6 [40, 91]
Bilateral/unilateral fit ratio (%)	72/28	77/23
Average 4FA HTL (dB HL) and range	39.6 [21.3, 55.0]	46.1 [33.8, 63.1]
Average LFA HTL (dB HL) and range	28.6 [5.0, 58.3]	33.6 [15.0, 58.3]
Average HFA HTL (dB HL) and range	49.3 [32.5, 67.5]	57.7 [43.3, 75.0]
Slope (dB) and range	20.7 [−19.2, 43.3]	24.3 [0.0, 54.2]

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