Long-Term versus Short-Term Hearing Aid Benefit

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Abstract

This study compared hearing aid benefit obtained 6 weeks and a minimum of 1 year after fitting to determine if changes occurred over time. Fifteen individuals with mild-to-moderate sensorineural hearing losses, who were successful users of linear amplification, were fitted binaurally with the Resound BT2 Personal Hearing System. These hearing aids are programmable in two frequency bands that provide wide dynamic range compression (WDRC) amplification. The manufacturer's recommended loudness growth in octave bands (LGOB) and audiogram programming algorithm and fitting procedures were used. Following an initial 6-week period and again following a minimum of 1 year of use, the Profile of Hearing Aid Benefit (PHAB) was administered. Similarly, speech recognition performance was tested using the Connected Speech Test (CST) in a six-talker speech babble at 50 dBA, +10 signal-to-noise (S/N); 60 dBA, +5 SNR; and 70 dBA, +2 SNR; and in quiet with a reverberation time of 0.78 seconds. Significant aided benefit was shown. These short-term benefit scores for the PHAB and CST were compared with those obtained after 1 year of full-time use. Results revealed no significant change in hearing aid benefit with long-term use, suggesting that a 6-week acclimatization period is sufficiently long for clinical trials of this type of WDRC amplification.

Key Words: Hearing aid benefit, long term, short term, wide dynamic range compression

Abbreviations: cd = critical difference, CST = Connected Speech Test, FDA = Food and Drug Administration, LGOB = loudness growth in octave bands, PHAB = Profile of Hearing Aid Benefit (BN = scale and subscale, speech in background noise; ES = scale, environmental sounds; QT = scale, speech in quiet; RC = scale, speech with reduced cues), PHAP = Profile of Hearing Aid Performance, PHS = Personal Hearing System, VC = volume control, WDRC = wide dynamic range compression

Several studies of auditory acclimatization have suggested that hearing aid benefit increases over time (e.g., Cox and Alexander, 1992; Gatehouse, 1992, 1993), whereas others have contradicted this finding (e.g., Bentler et al, 1993a, b; Humes et al, 1996). In a recent review of research, Turner et al (1996) discuss the many procedural variables that may confound the assessment of acclimatization. Overall, research that shows an increase in hearing aid benefit over time suggests that achievement of optimal use of new auditory cues from amplification occurs within the first few weeks of hearing aid use. Consequently, the Food and Drug Administration (FDA) has recommended a 4- to 6-week acclimatization period for clinical trials to support user benefit claims (FDA, 1994). However, newer hearing aid circuits with complex nonlinear processing, such as wide dynamic range compression (WDRC), alter the speech signal more drastically than frequency shaping in traditional linear circuits (Yund and Buckles, 1995). As a result, the time course for acclimatization may be longer than suggested by studies that have involved primarily linear amplification.

This is a follow-up study of 15 of 40 subjects who participated in a manufacturer-sponsored clinical trial of the ReSound BT2 Personal Hearing System (PHS) in 1995 (Walden et al, 1998). All had previous experience with linear am-
plification. The BT2 employs compression amplification over a wide range of input levels (45–85 dB SPL) with individually programmable crossover frequency, gain, and compression ratio (1:1–3:1) for low- and high-frequency bands (Moore et al, 1992). In general, the results of Walden et al (1998) revealed significant mean hearing aid benefit. In addition, individual data showed significant aided benefit for most subjects using both objective speech recognition measures and subjective field ratings. Further, aided Profile of Hearing Aid Benefit (PHAB) ratings for the WDRC instruments were significantly better in comparison to those for the linear instruments. Connected Speech Test (CST) measures were not obtained for the linear instruments. Approximately 1 year later, the 28 subjects who had elected to purchase the BT2 PHS following the original study were contacted by phone. The 15 subjects who reported full-time use of the BT2 PHS and were available to participate in this follow-up study were enrolled as subjects.

SUBJECTS

Subjects who participated in the initial 1995 clinical trial of the ReSound BT2 (1995) and who chose to purchase the instruments at the conclusion of the trial were recruited for follow-up (Walden et al, 1998). They were experienced users of linear amplification (a minimum of 1 year) prior to the initial BT2 trial. Only subjects who reported full-time, binaural use of the BT2 were included in this study. Another requirement for participation was that hearing threshold levels were within 10 dB of those obtained at the time of the initial trial and tympanometric and acoustic reflex data remained within the normal range. Additionally, the program parameters of the BT2 were unchanged and the results of electroacoustic analyses of the instruments were comparable to those obtained at the time of the initial clinical trial. The subjects used their own BT2 instruments for this study. Fifteen subjects who met these criteria were included in this follow-up study.

The mean age of the 15 subjects was 67.3 years (range: 55–75). The average lifetime hearing aid experience was 12.2 years (range: 3–12). The 1995 and 1997 audiometric data are summarized in Figure 1. On average, the subjects had bilaterally symmetric (not shown) moderate-to-severe, gradually sloping, sensorineural hearing loss with relatively good word recognition ability. The average length of time that the subjects had used the BT2 was 19.6 months (range: 16–22).

TEST PROCEDURES

The manufacturer's recommended loudness growth in octave bands (LGOB) and audiogram programming algorithm and adjustment procedures were used to fit the BT2 before the original clinical trial. These are described in detail in an earlier report (Walden et al, 1998) and are summarized briefly here. The algorithm incorporates results from loudness growth and pure-tone threshold measures. The crossover frequency and gain parameters were initially verified, and adjusted if necessary, based on the subject's loudness judgments of running speech presented at soft, conversational, and loud levels. Further "finetuning" adjustments were made after a 2-week trial period based on the subjects' experiences with the fitting, including an assessment of their use of a remote volume control (VC). Following this, an additional 4-week acclimatization period, without the VC, was provided during the original clinical trial before the administration of the initial test measures.

The dependent measures of the present follow-up study were the same as those used in the initial clinical trial in 1995 (Walden, 1997; Walden et al, 1998) and consisted of the PHAB (Cox and Gilmore, 1990; Cox and Rivera, 1992) and the CST (Cox et al, 1987, 1988). The Walter Reed protocol and rationale for the test materials and methods have been described in detail elsewhere (Walden, 1997) and will be discussed only briefly here.

The PHAB is a 66-item questionnaire that asks subjects to rate their hearing performance in a variety of everyday listening situations. A pencil-and-paper format and a 7-point response
scale with assigned percentages (always, 99%; almost always, 87%; generally, 75%; half-the-time, 50%; occasionally, 25%; seldom, 12%; never, 1%) were used. The subjects rated their performance twice, aided and unaided. The difference between the aided and unaided rating is the benefit score.

Items are grouped into four scales representing specific types of listening situations. The first scale (QT) describes relatively quiet listening situations and the second scale (RC) assesses performance in listening situations with reduced cues. The third scale (BN) consists of items dealing with speech understanding in background noise. The fourth scale (ES) includes statements involving environmental sounds such as warning sounds, music, voice quality, and naturalness of environmental sounds.

The CST consists of 48 passages produced by a female talker at a natural rate of articulation. There are 10 sentences per passage and 25 key words per passage are scored. A six-talker babble is recorded on a second track. One practice passage and six test passages (150 test items) were administered aided and unaided via one speaker at 0 degrees azimuth in four listening conditions: (1) relative quiet, 50 dBA, +10 S/N; (2) reverberation, 60 dBA, 0.78-seconds reverberation time; (3) moderate noise, 60 dBA, +5 S/N; and (4) high noise, 70 dBA, +2 dB S/N. The conditions were randomized into eight test sequences, which were presented in a counterbalanced order. The administration of the CST was partially automated. The passages and the associated babble were digitized and presented to subjects on line. Computer software automatically determined the randomization of the eight test conditions for the subject and the attenuator settings appropriate to the test condition. Test sentences were presented one at a time and the audiologist scored subject responses live. Although the subjects had been given a VC at the conclusion of the initial trial for use in daily living, they did not use it during the testing. Incidentally, at the time of the follow-up, most subjects did not have the VC with them and reported satisfaction with the adaptive gain function of the instruments.

In this follow-up study, a routine audiometric re-evaluation, verification of the BT2 program parameters, and electroacoustic analyses of the instruments were carried out first. Next, the PHAB was administered followed by the CST. Testing was accomplished in one 3-hour session.

**RESULTS AND DISCUSSION**

The primary goal of this study was to assess whether auditory acclimatization occurs beyond the initial 6 weeks of experience with hearing aids that employ WDRC. Comparisons of mean short-term and long-term benefit scores (BT2 aided minus unaided) for the PHAB scales are shown in Figure 2. Error bars in this and the next figure show +1 standard deviation. The results of two-tailed paired t-tests (p > .05) indicated no significant difference in benefit. The same comparison for the CST scores is presented in Figure 3. CST scores are reported in rationalized arcsine units (raus; Studebaker, 1985). For these data as well, the paired t-tests revealed no statistically significant differences between the initial (1995) and the follow-up (1997) evaluations for the 15 subjects. The error bars show 1 standard deviation.

![Figure 2](image-url) **Figure 2** Mean benefit (aided minus unaided success) PHAB scale scores obtained on the initial (1995) and the follow-up (1997) evaluations for the 15 subjects. The error bars show 1 standard deviation.

![Figure 3](image-url) **Figure 3** Mean CST benefit scores (aided minus unaided) for the four test conditions obtained on the initial (1995) and the follow-up (1997) evaluations. The error bars show 1 standard deviation.
Table 1  Mean Differences between the 1997 and 1995 Benefit Scores for the PHAB and the CST Data

<table>
<thead>
<tr>
<th>PHAB Scale</th>
<th>Mean Difference (%)</th>
<th>CST Condition</th>
<th>Mean Difference (rau)</th>
</tr>
</thead>
<tbody>
<tr>
<td>QT</td>
<td>1.7 (-4.5 to -7.9)</td>
<td>50 dBA, +10 S/N</td>
<td>1.7 (-6.8 to -10.2)</td>
</tr>
<tr>
<td>RC</td>
<td>-4.8 (-11.3 to -1.8)</td>
<td>60 dBA, Reverberation</td>
<td>-0.7 (-10.1 to -8.6)</td>
</tr>
<tr>
<td>BN</td>
<td>0.2 (-5.5 to -5.9)</td>
<td>60 dBA, +5 S/N</td>
<td>-0.8 (-7.7 to -6.1)</td>
</tr>
<tr>
<td>ES</td>
<td>2.2 (-6.8 to -10.2)</td>
<td>70 dBA, +2 S/N</td>
<td>1.8 (-6.2 to -9.8)</td>
</tr>
</tbody>
</table>

The 95 percent confidence intervals are shown in the parentheses.

between the short-term and long-term benefit scores (p > .05).

The transformation of the CST scores to rau is done to minimize possible ceiling and floor effects. However, a comparable transformation of the PHAB ratings is not routinely performed. Because the aided PHAB ratings were relatively high, they may have been susceptible to ceiling effects. Therefore, the PHAB data for each subject were expressed in terms of relative benefit according to the following formula:

$$\text{Relative benefit} = \frac{\text{Aided rating} - \text{Unaided rating}}{\text{100} - \text{Unaided rating}}$$

The paired t-tests for these transformed data did not reveal a significant difference in benefit between the 1995 and 1997 data for any of the four scales.

Recall that the number of subjects for this study was limited by the size of the original pool of subjects. Only 15 of the original 40 subjects met the selection criteria and were available to participate. This relatively small sample may have limited the power of the statistical tests to detect significant differences between the short-term and long-term CST and PHAB data. Assuming that differences in benefit scores of 10 percent or greater are clinically important on

Figure 4  Difference in long-term and short-term benefit scores (1997–1995) for the four PHAB scales for each subject. The horizontal lines on the graph of the BN scale/subscale data show the 95 percent critical difference (cd) value.
both the PHAB and the CST, the probability that the true differences between short-term and long-term benefit scores on these two measures exceed 10 percent can be assessed by computing 95 percent confidence intervals for the observed differences (Goodman and Berlin, 1994). These data are summarized in Table 1 and suggest that there is a low probability (≤ 0.05%) that long-term benefit exceeds short-term benefit by a clinically significant amount. This is also consistent with the individual subject data presented in Figures 4 and 5.

Figure 4 shows the differences for each of the PHAB scales between follow-up (1997) and the initial (1995) benefit scores for each subject. A positive value indicates an increase and a negative value a decrease in benefit with long-term use. Examination of these graphs reveals no tendency for hearing aid benefit to change toward one direction with long-term use, with the exception of the RC scale. For this scale, the long-term ratings for most subjects tended to indicate less benefit in comparison to the initial ratings. The horizontal lines for the BN scale (which is the same as the BN subscale) show the 95 percent critical differences (cds) reported by Cox and Rivera (1992) for PHAB subscales. It is apparent that the difference scores did not approach significance for any of the subjects. The cd values for benefit scores for the other full scales have not been reported to our knowledge, but they can be expected to be higher than those reported for Profile of Hearing Aid Performance (PHAP) scores—appropriate for comparing two unaided or two aided ratings (Cox and Rivera, 1992). These range from 16.1 percent to 22.7 percent for the different scales. Thus, the differences in PHAB ratings obtained in this study after 6 weeks and 1 year of hearing aid use generally appear attributable to measurement error, rather than to a true change in benefit over time.

Figure 5 shows the differences between follow-up and initial benefit scores for the four CST test conditions for each subject. Again, no trend for either greater or lesser long-term benefit is evident. Ninety-five percent cd values for CST benefit scores have not been reported. The 95 percent cd value for comparing two performance scores (e.g., aided vs unaided, two aided scores, etc.) for the 150-item test is 12.2 rau
SUMMARY AND CONCLUSIONS

The objective of the study was to assess possible differences in short-term versus long-term benefit derived from WDRC amplification for subjects who were previous users of linear amplification. It was assumed that the hearing-impaired persons who were accustomed to using linear amplification would be most likely to show acclimatization effects when switched to this unique nonlinear form of signal processing. The short-term measures were obtained after 6-weeks of use in the context of a manufacturer-sponsored clinical trial. The follow-up long-term measures were taken about 1½ years later. Only subjects whose audiometric results were stable and who reported full-time, binaural BT2 use with unchanged settings were included in this study. No significant increase in benefit was shown in group or individual data within this period. The results suggest that the FDA-recommended 6-week period of hearing aid use in clinical trials is sufficiently long for
evaluation of hearing aid benefit from the type of circuitry, subjects, and dependent measures used in this study. These results cannot answer the question whether a shorter than 6-week trial period would suffice.

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REFERENCES


