Comparison of Performance with Frequency Transposition Hearing Aids and Conventional Hearing Aids

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Abstract

Four experienced hearing aid users were evaluated using a frequency transposition (TranSonic) hearing system. Following a trial period, the Abbreviated Profile of Hearing Aid Performance (APHAB) and a variety of speech audiometric measures were used to compare the frequency transposition fitting with each subject's conventional hearing aids. A single-subject study design with a series of repeated measures permitted statistical analysis of differences in performance with the various amplification strategies. Two of the four subjects demonstrated statistically significant benefit with the frequency transposition device. Results show the efficacy of frequency transposition in improving speech understanding and quality of life in some individuals with severe-to-profound hearing loss. Overall, results suggest the need for evaluating the benefit of frequency transposition on an individual basis.

Key Words: Abbreviated Profile of Hearing Aid Performance (APHAB), frequency transposition, hearing aids

Abbreviations: APHAB = Abbreviated Profile of Hearing Aid Performance, AV = aversiveness of sounds, BN = background noise, EC = ease of communication, HA = conventional hearing aid, MCR = message-to-competition ratios, RV = reverberation, SSI = Synthetic Sentence Identification Test, TranSonic = TranSonic Model FT-40 MKII Frequency Transposition Hearing Aid System

Patients with severe-to-profound high-frequency hearing loss present a difficult rehabilitative/rehabilitative problem. Although conventional hearing aids can provide usable low-frequency information for these patients, the amplified high-frequency sounds of speech are often inaccessible due to the severity and configuration of the loss (Boothroyd and Medwetsky, 1992). Recently, however, improvements in hearing aid technology have provided new alternatives for patients with severe-to-profound sensorineural hearing loss (Rosenhouse, 1990; Davis-Penn & Ross, 1993; Chute et al, 1995).

The use of frequency shifting techniques with hearing-impaired listeners is not a new concept. As early as the 1950s and 1960s, investigators attempted to use frequency lowering techniques in amplification and training for hearing-impaired patients (Bennet and Byers, 1967; Beasley et al, 1976). Bennett and Byers (1967) eloquently describe the logic of using frequency transposition as an effort to "match the bandwidth of the incoming speech signal to the damaged ear's limited band of greatest sensitivity [rather than attempting] to force the damaged [high frequency] sensory units to respond." Many methods have been used to achieve non-proportional or proportional frequency transposition; however, there have been no widely used wearable devices or training tools (Beasley et al, 1976; Davis-Penn and Ross, 1993).

Disproportionate frequency shifting methods such as carrier modulation and the shifting of speech frequencies by a constant value generally resulted in unnatural voice quality and
little or no gain in speech understanding (Bennett and Byers, 1967; Foust and Gengel, 1973; Velmans and Marcuson, 1983; AVR Communications Ltd., 1994). These methods of nonproportional transposition do not preserve the relative relationships of the spectral components of the speech signal. Hence, the output pattern may be confusing to the listener.

Proportional frequency shifting, using a "slow play" method, is another technique that has been used in the past and has been applied most recently in the TranSonic device (Bennett and Byers, 1967). In this method, speech is recorded then played back at a slower speed than employed for recording, thus preserving the relative spectral positions of the speech components. However, fitting a tape recorder into a wearable device and dealing with the prolongation of the time base of the slow tape playback precluded the development of a wearable transposition device in the past.

One type of frequency shifting device that has received moderate use for the past decade is the EMILY This device is designed on the principle that spectral information in the 1000-Hz to 2000-Hz region is highly important for speech perception. The EMILY device detects formants and phonetic transitions in this frequency region and shifts duplicates of the detected features into higher and/or lower frequency regions in which the features may be better perceived. This frequency shifting to reinforce selected spectral elements occurs in real time. Although this technique is available in a wearable device and has shown promise for patients with a wide range of hearing losses, there is only a limited amount of clinical data available on the device.

The TranSonic Model FT-40 MKII frequency transposition hearing aid system is a powerful amplification device that incorporates slow-play frequency transposition (AVR Communications, 1994). The input signal is processed using proportionally slow-play frequency transposition in order to overcome limitations of conventional hearing aids. Through the use of a magnetic tape with an electronic storage device, the TranSonic system proportionally shifts and narrows the speech signal in "perceptual real time." The TranSonic also provides a dynamic consonant boost (DCB) to weak, high-frequency speech signals. The TranSonic is designed to provide as much usable speech information as possible to the user in a low-frequency range. In theory, the transposition of inaudible high-frequency consonants into an auditorily accessible low-frequency region should provide an advantage over conventional hearing aids for patients with little or no residual hearing in the high frequencies.

The expansion of amplification fitting options for individuals with severe-to-profound hearing loss is encouraging, yet it leads to new questions and concerns. Since candidacy criteria for devices such as the TranSonic and cochlear implants overlap, audiologists are faced with the task of determining which audiologic factors may lead to better prognosis with a specific device or combination of devices (Cochlear Corporation, 1995). Davis-Penn and Ross (1993) have suggested that "the TranSonic FT-40 fills an amplification fitting niche somewhere between conventional hearing aids and cochlear implants," but the boundaries of that niche are currently still undefined. Questions remain regarding the degree of benefit provided by the frequency transposition technology as compared to conventional hearing aids and/or cochlear implants.

The primary purpose of this study was to evaluate performance of the TranSonic frequency transposition hearing aid system as compared to a conventional hearing aid fitting. Comparisons were made using a variety of speech audiometric measures due to the varying speech understanding abilities of individuals with severe and profound hearing impairment. Statistical analysis of performance was made at the level of the individual subject in order to determine whether "significant" benefit could be demonstrated with a particular device. The secondary purpose of this study was to investigate the utility of our approach for determining the appropriate fitting option for each subject.

**METHOD**

**Subjects**

Four previous hearing aid users with severe-to-profound sensorineural hearing loss were recruited from the Audiology Service of The Methodist Hospital. All subjects fit the typical TranSonic fitting range (bilateral, moderate-to-profound sensorineural loss in the low frequencies and little or no residual hearing in the high frequencies). Subjects had no history of neurologic involvement. Ages ranged from 20 to 51 years. The group included three men and one woman. Prior to the study, all subjects had worn powerful binaural behind-the-ear (BTE) hearing aids for many years (7–43 years). Hearing aids were found to be working within manufacturer’s
specifications and appropriate for degree and configuration of loss.

**Apparatus**

All audiometric testing was conducted using standard clinical audiometers (GSI model 10). Speech audiometric materials were recorded on magnetic tape and presented either via tube-phones (Etymotic 3A: unaided condition) or in the sound field with subjects seated approximately 1 meter from, and directly facing, a loudspeaker (aided conditions).

**Procedure**

**Initial Testing**

Subjects were evaluated over at least four test sessions at 2-week intervals. Initial testing involved gathering data on each patient's audiologic status and current hearing aid fitting. During session one, aided and unaided audiograms were obtained. Aided performance on speech audiometric tests was assessed using a cochlear implant test battery (Cochlear Corporation, 1995), which included the following measures:

1. **Four Choice Spondee Test**—a 20-item closed-set word identification test in which the subject must choose the correct spondee from a set of four choices.
2. **Iowa Vowel Recognition Test**—a 45-item closed-set word identification test in which the subject must choose among nine words differing in medial vowel (i.e., "heed," "had," "heard," "who'd," "hod," "hid," "hood," "head," "hawed"); the subject was instructed to write each vowel heard on a response form.
3. **Iowa Medial Consonant Recognition Test**—a 70-item test of nonsense syllables in which the subject must choose among 14 medial consonants (i.e., "aba," "aka," "ada," etc); the subject was instructed to write each consonant heard on a response form.
4. **CID Everyday Sentence Test**—a list of 40 sentences presented in an open-set format. The subject was instructed to repeat each sentence; scoring is based on the number of correct key words.
5. **Monosyllabic Word Test (NU #6)**—a set of 50 consonant-vowel-consonant words presented in an open-set format; the subject was instructed to write each word on a response form.

All measures were presented in an auditory-only mode, where subjects received no visual or contextual cues. This test battery was chosen because it is appropriate for individuals with severe-to-profound hearing loss, is widely used, and measures a range of performance from simple closed-set word identification to more difficult open-set speech recognition.

Subjective assessment of hearing aid benefit was also evaluated during session one by having each subject complete the Abbreviated Profile of Hearing Aid Performance (APHAB) questionnaire (Cox and Alexander, 1995). The APHAB is a 24-item questionnaire used to quantify the perceived disability associated with hearing impairment and the reduction of disability achieved with use of amplification. Using a paper and pencil format, subjects rated the amount of listening difficulty experienced on four subscales: ease of communication (EC), reverberation (RV), background noise (BN), and aversiveness of sounds (AV). For the three speech subscales (EC, RV, and BN), a difference of 26 percent between two conditions (aided vs unaided or fitting #1 vs fitting #2) is the critical difference associated with a 95 percent confidence interval. Results were graphed and critical differences were evaluated.

Test results obtained during session one were used to confirm TranSonic candidacy, to determine initial TranSonic processor settings, and as a baseline measure of performance. In addition, each subject was classified as to whether or not he/she met the criteria for cochlear implantation. Speech audiometric tests in which subjects scored between 20 and 75 percent were chosen for use in later sessions designed to compare performance using conventional hearing aids with the TranSonic system. In two cases, the CID Everyday Sentence Test scores exceeded 75 percent. Test presentation level was therefore decreased to make the task more difficult for later comparison testing.

**Fitting the TranSonic Device**

During either the first or second session, patients were fit with the TranSonic device. All subjects used the TranSonic in wireless configurations, using two BTE spatially limited FM receivers (SLRs) and a belt antenna to transmit the signal from the processor to the SLRs.

The TranSonic processor proportionally shifts and compresses the frequency of the speech signal into a lower frequency range (AVR Communications, 1994). The processor determines
whether the spectral location of the energy peak is concentrated above or below 2500 Hz. If the spectral energy is above 2500 Hz, the signal is regarded as a consonant and the consonant coefficient (Zc) is activated. If the spectral energy is below 2500 Hz, the signal is regarded as a vowel and the vowel coefficient (Zv) is activated. Activation of either the Zc or Zv coefficients results in shifting the speech spectrum into a lower frequency range. In addition, a special circuit called the dynamic consonant boost (DCB) may be adjusted to increase the level of weaker consonants.

A fitting formula based on unaided audiometric results was used for the initial device fitting (AVR Communications, 1993). Adjustment to the Zc, Zv, DCB, and volume controls was made using (1) the Phoneme Audibility Assessment tasks and (2) soundfield thresholds to narrow-band noise, as recommended by AVR Communications. The TranSonic settings were readjusted, if needed, during the session scheduled 2 weeks post fitting.

Conventional Hearing Aids vs TranSonic

During the third and fourth sessions (3–6 weeks post fitting), each subject's performance using conventional hearing aids was compared to her/his performance with the TranSonic amplification system. Both the conventional hearing aids and TranSonic system were fit binaurally in all subjects. Speech audiometric data were obtained for both fitting strategies using one or more tests selected from the cochlear implant test battery used during the first session. For ease of presentation, nonsense syllables, words, and sentences from two Cochlear Corporation tapes (randomizations 1 and 2) were combined on a third tape in order to produce a successive series of 100 items per test. For each test, 100 items were presented in 10 test blocks with 10 items per block. The subject wore the conventional hearing aids for five of the blocks and the TranSonic device for five of the blocks. The order of device use was randomized across the trials with the constraint that each device was not used for more than two successive blocks.

During the final session, the APHAB was completed following a minimum of 4 weeks use of the TranSonic device. Subjective assessment of benefit received from the two devices was determined by comparing identical APHAB questionnaires at the first session (for conventional hearing aid) and last session (for TranSonic). Subjects were not able to view the APHAB they had executed for their conventional hearing aids while they ranked the TranSonic device.

Statistical Approach

For each speech audiometric test completed, the percent correct scores for each device were compared using the Mann Whitney U test (Siegel, 1956), a nonparametric analog of Student's t-test. Results from five blocks of a test with a given device were averaged to obtain an overall mean for that device. The variability among scores across the five blocks provided an estimate of error variance. Statistical significance was evaluated at the 0.05 level of confidence.

CASE REPORTS

Case 1

Case 1 is a 20-year-old man with sloping moderate-to-profound sensorineural hearing loss bilaterally. Figure 1a shows unaided pure-tone, air-conduction audiograms. Thresholds lie well within the typical fitting range recommended for the TranSonic device. Case 1 has successfully used binaural, BTE hearing aids for "as long as he can remember." His aided performance on the CID Everyday Sentence Test, presented at a comfortable listening level of 65 dB HL, was 89 percent. Results suggest substantial benefit from conventional amplification.

Results

Figure 1b shows an aided narrow-band-noise audiogram comparing the conventional hearing aid fitting with the TranSonic fitting. The audiogram shows slightly improved thresholds for the 250-Hz to 3000-Hz region and

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markedly enhanced responses to 4000-Hz and 6000-Hz stimuli with use of the TranSonic device. It is noteworthy to point out that real-ear gain with the BTEs appears to be better than expected for the degree of sensitivity loss, especially in the high frequencies. At 4000 Hz in the left ear, for example, the unaided threshold is 120 dB HL, while the aided threshold is 55 dB HL, a surprising gain of 65 dB. This unexpected degree of improvement may be due to a number of factors, including the following:

1. There were differences in calibration procedures for earphone in comparison to soundfield measures. There was no attempt to match earphone data with soundfield data. Since we were primarily interested in the differences between devices rather than overall gain, unaided soundfield thresholds were not measured for direct comparison with aided thresholds.

2. A 3- to 6-dB binaural advantage may be observed since soundfield thresholds were obtained binaurally, while pure-tone thresholds were obtained for each ear separately.

3. Narrow bands of noise have some energy at frequencies below the center frequency, thus inflating thresholds slightly.

4. Ear canal resonance in the high frequencies may offer some additional gain.

Figure 1c shows performance scores (percent correct) for the Iowa Medial Consonant Recognition Test and CID Everyday Sentence Test obtained 4 weeks post TranSonic fitting. Testing was performed at 50 dB HL. Each panel shows both the individual block scores over the 10 sequential blocks and the mean scores for the conventional hearing aid versus TranSonic conditions. Mean scores for the Iowa Medial Consonant Recognition Test were 62 percent and 66 percent for the conventional hearing aid and TranSonic conditions, respectively. Differences on this test were not statistically significant. Mean scores for the CID Everyday Sentence Test were 51 percent for the hearing aid condition and 88 percent for the TranSonic condition. Differences on the CID Everyday Sentence Test were statistically significant (p = .009).

The APHAB results are shown in Figure 1d. For the three speech communication subscales, Case 1 indicated a lower percentage of problems with the TranSonic device. Using the TranSonic device, a 30 percent reduction in percent of listening problems was evidenced in the RV condition. This large difference in scores exceeds the 95 percent critical difference value for APHAB scores as determined by Cox and Alexander (1995), indicating superiority of the TranSonic fitting over the conventional hearing aid fitting for at least one listening condition. At the conclusion of the study, Case 1 reported that
his ability to understand speech was best with the TranSonic due to improved sound quality and increased loudness of sounds, which he is unable to perceive with his conventional aids. Overall results for Case 1 demonstrated significantly better performance using the TranSonic device compared to his conventional hearing aids.

Case 2

Case 2 is a 46-year-old man with a severe sensorineural hearing loss through 750 Hz and a profound sensorineural hearing loss from 1000 Hz to 8000 Hz bilaterally. Figure 2a shows unaided pure-tone, air-conduction audiograms. Thresholds lie well within the typical fitting range recommended for the TranSonic device. Case 2 has successfully used binaural BTE hearing aids since the age of 3. His aided performance on the CID Everyday Sentence Test, presented at a comfortable listening level of 65 dB HL, was 87 percent. Results suggest substantial benefit from conventional amplification.

Results

Figure 2b shows an aided audiogram comparing the conventional hearing aid fitting with the TranSonic fitting. The narrow-band-noise audiogram shows slightly improved thresholds for the 250-Hz to 750-Hz region and substantially better threshold responses from 1000 Hz through 6000 Hz with use of the TranSonic device.

Figure 2c shows percent correct scores for the Iowa Medial Consonant Recognition Test and CID Everyday Sentence Test obtained 6 weeks post TranSonic fitting. Testing was performed at 50 dB HL. Mean scores for the Iowa Medial Consonant Recognition Test were 48 percent and 64 percent for the conventional hearing aid and TranSonic conditions, respectively. Differences on this test were not statistically significant. Mean scores for the CID Everyday Sentence Test were 86 percent for the hearing aid condition and 94 percent for the TranSonic condition. This difference was statistically significant (p = .05). Although the mean percent correct scores for the CID test are only slightly different, variability was small and each TranSonic
CASE 2

Figure 2c Comparison between conventional hearing aids and Transonic device on the Iowa Medial Consonant Recognition Test and the CID Everyday Sentence Test for Case 2. Each panel shows both sequential trial block and mean percent correct scores for target identification. Wide diagonal stripes indicate individual block scores and mean scores, averaged across the five trial blocks, for the conventional hearing aid condition; narrow diagonal stripes indicate individual block scores and mean scores for the Transonic condition.

trial exceeded the best hearing aid trial. Only three trials were completed with each device due to the very high scores and the possibility of familiarization with repeated sentences.

Figure 2d shows results on a third speech audiometric test that was completed to further assess the benefit achieved by Case 2 with the Transonic device. The Synthetic Sentence Identification (SSI) test was administered in sound field at varying message-to-competition ratios (MCRs). Subject 2's ability to identify nonsense sentences in the presence of a background noise of continuous speech was similar with the two devices for most conditions. However, at a very difficult MCR of -20 dB (sentences 20 dB softer than background noise), Case 2 scored 40 percent correct with the Transonic device and 0 percent correct with his conventional hearing aids. This appears to be a significant difference for one listening condition, but no statistical analysis is available on these data.

The APHAB results are shown in Figure 2e. Scores for all four conditions indicate essentially no difference between the amplification strategies. Although APHAB results do not show one device to be superior to the other, Case 2 did report that he preferred the Transonic device because he felt it was more powerful and allowed him to hear more sounds with less mental effort. Overall results for Case 2 did suggest significantly better performance using the Transonic system as compared to his conventional hearing aids.

Case 3

Case 3 is a 51-year-old man with a severe-to-profound bilateral sensorineural hearing loss. Figure 3a shows unaided pure-tone, air-conduction audiograms. Thresholds lie well within the typical fitting range recommended for the Transonic device. Case 3 has a history of a progressive hearing loss that began in 1976. He has used various binaural hearing aids since the onset of the loss. Based on the initial evaluation, Case 3 does fit the criteria for cochlear implantation. His aided performance on the CID Everyday Sentence Test was 41 percent at a comfortable listening level of 65 dB HL and decreased to 24 percent at 55 dB HL. Results suggest minimal benefit from conventional amplification.

Figure 3b shows an aided audiogram comparing the conventional hearing aid fitting with the Transonic fitting. The narrow-band-noise

Figure 2d Comparison between conventional hearing aids and the Transonic device on the Synthetic Sentence Identification (SSI) Test administered at various message-to-competition ratios (MCRs) for Case 2. The shaded region represents performance of normal-hearing persons.
Case 3

Age: 51  Sex: M

Right Ear  250 1000 4000 250 1000 4000 dB

Left Ear  0 4000 250 1000 4000 dB

Pure Tone Audiology

Too Much Residual Hearing

Patient's Fitting Range

Typical Fitting Range

Not Enough Residual Hearing

Figure 3a  Unaided pure-tone audiograms for Case 3. The shaded regions indicate fitting range for the TranSonic device.

The audiogram shows similar thresholds for both devices through 1000 Hz. Better thresholds were obtained from 1500 Hz through 6000 Hz with use of the TranSonic device.

Figure 3c  Comparison between conventional hearing aids and TranSonic device on the Iowa Medial Consonant Recognition Test and the CID Everyday Sentence Test for Case 3. Each panel shows both sequential trial block and mean percent correct scores for target identification. Wide diagonal stripes indicate individual block scores and mean scores, averaged across the five trial blocks, for the conventional hearing aid condition; narrow diagonal stripes indicate individual block scores and mean scores for the TranSonic condition.

and TranSonic conditions, respectively. Differences on this test were not statistically significant. Mean scores for the CID Everyday Sentence Test were 24 percent for the hearing aid condition and 39 percent for the TranSonic condition. This difference was not statistically significant.

The APHAB results are shown in Figure 3d. Scores for all four conditions indicate essentially no difference between the amplification strategies. In addition, Case 3 reported that he was not satisfied with the TranSonic fitting. Although he reported that he could hear soft speech sounds better with the TranSonic device, he did not like the harsh sound quality of some frequency shifted sounds, especially /s/ and /sh/ sounds at the ends of words. Due to demands of his work environment and his familiarity with use of his conventional hearing aids in conjunction with an FM auditory trainer, Case 3 did not use the TranSonic for a great deal of time during the study. Overall results suggest no significant differences between performance with the two amplification strategies, yet Case 3 definitely preferred his own hearing aids. It should be noted that although the TranSonic did not provide statistically significant benefit for Case 3, the TranSonic fitting did not significantly decrease Case 3's speech understanding abilities on any of the tests used.

Case 4

Case 4 is a 42-year-old woman with a history of chronic renal failure who currently undergoes kidney dialysis treatments four times per day. Sensorineural hearing loss resulting from ototoxicity occurred in July 1988 following a
kidney transplant that failed. Hearing loss was progressive. Profound hearing loss was observed in 1991. She reports receiving very minimal benefit from hearing aids since 1991. Case 4 was evaluated using our cochlear implant test battery and found to be a suitable candidate for cochlear implantation. However, she was hesitant to undergo any additional surgeries due to her past history and present medical condition.

Results

Figure 4a shows Case 4's unaided pure-tone audiograms. Air-conduction thresholds fell within the typical fitting range recommended for the TranSonic hearing aid. On our test battery, presented at a comfortable listening level of 70 dB HL, Case 4 scored at chance level on all closed-set measures and 0 percent on the CID Sentence Test and the Monosyllable Word Test. Results show that she receives virtually no benefit from conventional amplification.

Figure 4b shows an aided narrow-band-noise audiogram comparing the conventional hearing aid fitting with the TranSonic fitting. The audiogram shows markedly improved thresholds across the frequency range from 250 Hz to 6000 Hz for the TranSonic device.

Figure 4c shows percent correct scores for the Four Choice Spondee Test obtained 4 weeks post TranSonic fitting. Mean scores were 42 percent and 30 percent for the conventional hearing aid and TranSonic conditions, respectively. Differences in performance were not statistically significant. The Four Choice Spondee Test was the only test selected to compare devices statistically, because, during the
CASE 4

Four Choice Spondees

Figure 4c Comparison between conventional hearing aids and Transonic device on the Four Choice Spondee Test for Case 4. Each panel shows both sequential trial block and mean percent correct scores for target identification. Wide diagonal stripes indicate individual block scores and mean scores, averaged across the five trial blocks, for the conventional hearing aid condition; narrow diagonal stripes indicate individual block scores and mean scores for the Transonic condition.

Everyday Sentence test for both hearing aid and Transonic conditions.

The APHAB results are shown in Figure 4d. Using the Transonic hearing aid, Case 4 demonstrated a lower percentage of problems only for the AV condition. This difference was not considered significant based on critical difference values for a 95 percent confidence interval (Cox and Alexander, 1995). Case 4 reported that she achieved greater sound awareness using the Transonic device, but continued to report significant difficulties in speech understanding.

Overall, despite better aided thresholds, Case 4 was not considered a successful user of the Transonic device. At this point she chose to undergo cochlear implant surgery.

DISCUSSION

Transonic vs Conventional Hearing Aids

As expected, all four of our subjects demonstrated improvement in sound detection, particularly in the high frequencies, using the Transonic device. Two of these subjects (Cases 1 and 2) also showed significant improvement in speech understanding with frequency transposition. These two subjects, who were classified as good conventional hearing aid users, were able to benefit even more from the additional high-frequency information provided by the Transonic device. We have informally observed this trend with four or five additional patients. Those who were very poor hearing aid users, many of whom were implant candidates, were less likely to benefit from frequency transposition. A systematic analysis would be a topic for future research.

For this study, we used measures ranging from word identification in a closed set of four items to open-set speech recognition. A variety of speech perception measures was necessary in order to avoid floor or ceiling effects. Subjectively, the subjects made two important observations. They were very pleased with reduced presence of acoustic feedback and noticed that listening was “easier.”

The present results suggest that frequency transposition is efficacious in improving speech understanding and quality of life in some, but not all, individuals with severe-to-profound hearing loss. Frequency transposition, as presented in the Transonic system, is a viable option for those persons with usable low-frequency hearing who demonstrate appropriate motivation and receive appropriate rehabilitation. For these subjects, the benefits of the device must outweigh the negatives associated with its larger size, including the use of ear level receivers, a belt antenna, and a signal processor.

It is important to note that although not all subjects performed better with the Transonic device, no subject performed significantly less well. In this study, subjects had only 4 to 6 weeks to adjust to the Transonic device. It is possible that, given more time, the two subjects who reported little benefit may have shown more improvement.

Figure 4d Comparison between conventional hearing aids and Transonic device on four subscales of the APHAB questionnaire for Case 4. EC = ease of communication, RV = reverberation, BN = background noise, and AV = aversiveness of sounds. Higher scores indicate a greater percentage of problems.
The results of this study highlight the fact that there is not one particular technology that works best for all individuals within a certain fitting range. Cases 1 and 2, for example, performed best using frequency transposition. Case 3 was most satisfied using his conventional hearing aids along with an FM assistive listening device, and Case 4 performed poorly with both systems. Overall, results suggest the need for evaluating the benefit of frequency transposition on an individual basis.

Accountability

In view of the evolving alternatives for the management of hearing impairment and the evolving nature of the health care system, the issue of accountability must be addressed. Special circuitry in hearing aids or processing schemes such as that required for frequency transposition results in costs that may be two to three times greater than for a conventional hearing aid. In this study, we used a methodology in which serial samples of data (five blocks per condition) were collected from each individual. This testing protocol permitted an estimate of error variance and, therefore, use of a statistical test, the Mann Whitney U Test. This approach made it possible to take into account variability of the person being tested when determining benefit with a specific fitting option (TranSonic frequency transposition) for that individual. This type of approach may become more and more useful as both consumers and third-party payers request justification for specific fitting options (Chmiel and Jerger, 1995). Unlike nonparametric measures, parametric tests such as the Student’s t-test require the assumption of serial independence (Barlow and Hersen, 1984) and that the population distribution from which the sample data are drawn has a normal distribution (Mood, 1950). In addition, an approach such as the binomial model proposed by Thornton and Raffin (1978) considers only the stability of a percent correct score, whereas measures such as the Mann Whitney U Test take into account the performance stability of the subject being tested. Thus, nonparametric measures may be particularly valuable for supporting a specific intervention strategy for a particular hearing-impaired individual.

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