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Performance of Custom-Fit versus Fixed-Format Hearing Aids for Precipitously Sloping High-Frequency Hearing Loss

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Abstract

This study compared the real-ear response provided by custom-fit hearing aids to the closest matching fixed-format disposable hearing aids in patients with precipitous high-frequency hearing loss. Laboratory and field measures of aided performance were obtained to compare patient performance with the custom-fit and fixed-format hearing aids. In addition, coupler versus real-ear response differences were compared for the two hearing aid types. The results revealed that relatively close approximations to the real-ear aided responses of the custom-fit instruments were possible for most participants using seven fixed acoustic formats. No significant differences in mean performance between the two instrument types were observed for aided speech recognition or field ratings of aided performance, although mean patient satisfaction was lower for the disposable hearing aids. The real-ear to coupler difference was greater for the disposable hearing aid than for the custom-fit instruments, presumably owing to its deeper insertion into the ear canal.

Key Words: Benefit, custom fit, disposable, hearing aids, real-ear aided response, satisfaction, speech recognition

Abbreviations: AASC = Army Audiology and Speech Center; APHAB = Abbreviated Profile of Hearing Aid Benefit; CIC = completely in the canal; HINT = Hearing in Noise Test; ITC = in the canal; REAG = real-ear aided gain; REAR = real-ear aided response; RECD = real-ear to coupler difference; RTS = reception threshold for sentences; SADL = Satisfaction with Amplification in Daily Life; SDHA = Songbird Disposable Hearing Aid; WDRC = wide dynamic range compression

Sumario

Este estudio compara las respuestas medidas en oído-real (real-ear) generadas por un auxiliar auditivo construido y adaptado a la medida, con las de un auxiliar auditivo descartable de formato fijo, en pacientes con una pérdida auditiva de caída abrupta en altas frecuencias. Se obtuvieron mediciones de rendimiento amplificado, tanto de laboratorio como de campo, para comparar las respuestas de pacientes con auxiliares auditivos construidos a la medida y con aquellos de formato fijo. Además, se compararon las diferencias de respuesta para los dos tipos de auxiliar auditivo, tanto en acoplador como en oído-real. Los resultados revelaron que era posible obtener, para la mayor parte de los participantes, una relativamente cercana aproximación a la respuesta amplificada en oído-real de los instrumentos construidos a la medida, utilizando siete formatos acústicos fijos. No se observaron diferencias significativas en el rendimiento promedio entre los dos tipos de instrumentos para el reconocimiento del lenguaje amplificado o para evaluaciones de campo de rendimiento amplificado, aunque la satisfacción media del paciente fue menor para los auxiliares auditivos descartables. Las diferencias entre el oído-real y el acoplador fueron mayores para los auxiliares auditivos descartables que para los instrumentos construidos a la medida, presumiblemente debido a su inserción más profunda en el canal auditivo.

Palabras Clave: Beneficio, adaptación a la medida, descartable, auxiliar auditivo, respuesta amplificada en oído-real, satisfacción, reconocimiento del lenguaje

Abreviaturas: AASC = Centro de Audiología y Lenguaje de la Armada; APHAB = Perfil abreviado de beneficio del auxiliar auditivo; CIC = completamente dentro del cana; HINT = Prueba de Audición en Ruido; ITC = en el canal; REAG = ganancia amplificada en oído-real; REAR = respuesta amplificada en oído-real; RECD = diferencia de oído-real a acoplador; RTS = umbral de recepción para frases; SADL = satisfacción con la amplificación en la vida diaria; SDHA = audífono descartable songbird; WDRC = compresión amplia de rango dinámico

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Hearing aids are routinely custom fit to hearing-impaired patients based on a variety of individual audiometric measures, including threshold sensitivity, loudness discomfort levels, and growth of loudness curves. Many fitting algorithms have been published to derive an amplification prescription (i.e., gain-by-frequency response) for the patient (Byrne and Dillon, 1986; Killion, 1994; Cox, 1995; Seewald et al, 1996). With the same audiometric measures as input, each algorithm will prescribe a slightly different gain function. Modern programmable hearing aids allow the audiologist to approximate such custom prescription targets with a high degree of precision. Several prescriptive algorithms have achieved some degree of clinical acceptance; however, no single prescriptive formula is used universally. Further, limited data exist to suggest the degree of precision that is required in matching prescription target gain values to achieve optimal user benefit and satisfaction.

Recently, disposable hearing aids were introduced commercially (Staab et al, 2000). The Songbird™ Disposable Hearing Aid (SDHA) cannot be individually adjusted to custom fit a patient's hearing loss. Rather, it is available in a limited number of fixed acoustic prescriptive formats. Audiometric templates provided by the manufacturer may be used to estimate the most appropriate fixed electroacoustic configuration, based on the patient's audiogram (McCandless et al, 2000). Preliminary behavioral studies with this device, using standard tests of speech recognition and field measures of hearing aid performance, suggested that it provided significant benefit to patients with mild-to-moderate hearing loss (Preves, 2000; Staab and Preves, 2000). Additionally, an electroacoustic assessment revealed that its frequency response was broader and smoother and had lower levels of circuitry noise than comparison instruments that included fully digital and digitally programmable devices (Moore et al, 2001).

In the absence of clinical data comparing patient performance with disposable hearing aids to that with custom-fit instruments, it is unclear whether user benefit and satisfaction are compromised through the use of fixed formats. In this study, patients who were successful users of custom-fit hearing aids were fit with the SDHA format that most closely approximated the real-ear aided response (REAR) provided by their own hearing aids. Standard laboratory measures of aided speech understanding were obtained with the disposable hearing aids and the patient's own custom-fit instruments to compare the performance of the two hearing aid types in a controlled listening environment. Additionally, field ratings of hearing aid benefit and satisfaction were obtained to determine how each performed in everyday listening. Both 2-cc coupler and in situ real-ear response measures were obtained with the patient's own hearing aids and the SDHA format that most closely approximated the real-ear response provided by the patient's custom-fit hearing aids. These electroacoustic measures revealed how closely the custom prescription was approximated by the fix-format disposable instrument. Additionally, these data were analyzed to determine if the disposable instrument provided relatively more sound pressure at the tympanic membrane owing to its deep insertion into the external ear canal.

METHOD

Participants

Fifteen adult males with acquired sensorineural hearing losses served as participants. All volunteered and provided informed consent. As conditions of enrolment, participants had pure-tone thresholds within the fitting ranges of the disposable instrument as specified by the manufacturer, threshold sensitivity that decreased at least 15 dB per octave and at least 35 dB between 1000 and 4000 Hz, and pure-tone sensitivity that did not differ between ears by more than 25 dB at any audiometric test frequency from 500 to 4000 Hz. In addition, unaided monosyllabic word recognition ability in quiet (recorded Northwestern University Auditory Test No. 6 [NU-6]) was 50% or better in each ear at a comfortable listening level. Sensorineural hearing loss (cochlear site of lesion) was verified by differences between air- and bone-conduction thresholds of 10 dB or less, by normal tympanograms (Type A, Jerger classification), and by the presence of contralateral acoustic reflexes.

Participants had been custom fit binaurally with programmable single- or dual-channel wide dynamic range compression (WDRC) completely-in-the-canal (CIC), mini-canal, or in-the-canal (ITC) hearing aids at the Army Audiology and Speech Center (AASC) at least 3 months prior to their participation in the study but not more than 13 months preceding enrolment. As a condition of enrolment, participants reported using their current custom-fit hearing aids a minimum of 4 hours per day. Further, those instruments had to be functioning according to manufacturer's specifications at the time of enrolment in the study, as determined by 2-cc coupler electroacoustic measurements. Finally, the disposable hearing aid had to provide an acceptable fit to the participant's ears. Specifically, the device could protrude no more than 5 mm from the ear canal aperture, and there could be no unresolved comfort or feedback problems at the time of fitting.

Hearing Aids

The SDHA used in this study was an analog single-channel, WDRC hearing aid with a compression threshold of 60 dB SPL and a compression ratio of 2.7 to 1. The amplifier provided treble increases at low level processing (McCandless et al, 2000). At the time of this study, it was available in six fixed electroacoustic configurations that varied according to two audiometric configurations ("S" [sloping] and "F" [flat]) and three overall gain categories ("40" [mild], "55" [mild-moderate], "70" [moderate-moderately severe]), as well as a low-gain format ("Enhancer") that provided an average of 5-dB coupler gain limited to the higher frequencies. The disposable instrument was available in three tip sizes (8, 9, and 10 mm). The built-in battery provided approximately 40 days of use based on approximately 12 hours of use per day.

Performance with the disposable hearing aids was compared with performance with the participants' own hearing aids previously fit at the AASC. These custom-fit instruments represented different manufacturers and models, but all featured single- or dual-channel WDRC processing. The disposable format that most closely matched the real-ear response provided by the participants' own hearing aids was selected for use in the study.

Procedures

Participation in the study required two clinic visits. Average time between the two visits was 14.0 days, with a range of 8 to 30 days.

Visit 1

The procedures performed at visit 1 were as follows:

1. *Audiometric evaluation.* All participants recruited for the study had received a complete audiometric evaluation at the AASC within 13 months preceding their enrolment in the study. Standard diagnostic audiometric tests were readministered to determine candidacy for the protocol. Pure-tone air-conduction thresholds were obtained for the octave and interoctave frequencies from 250 through 8000 Hz. As a condition of enrolment, air-conduction thresholds from 500 through 4000 Hz had to be within ±10 dB of those obtained at the time the participant's custom instruments were fit. Bone-conduction testing was administered if the air-conduction threshold was more than 5 dB poorer than the participant's most recent test results. Word recognition testing, under earphones, was accomplished at the participant's most comfortable listening level using a recorded 25-word NU-6 monosyllabic word list. Tympanometry and contralateral and ipsilateral acoustic reflexes were obtained for each ear.
2. *Field measures with custom hearing aids.* Two standardized questionnaires were administered to obtain subjective ratings of hearing aid benefit and satisfaction in daily living with the participant's own custom-fit hearing aids. The Abbreviated Profile of Hearing Aid Benefit (APHAB) was used to assess hearing aid benefit in everyday listening situations (Cox and Alexander, 1995). It is a 24-item self-assessment inventory that provides four scale scores describing hearing aid benefit in common everyday listening situations, including relative quiet, reverberation, background noise, and aversive sounds. The participant completed the APHAB for both unaided and aided listening conditions. The participant's satisfaction with his own custom hearing aids was assessed using the Satisfaction with Amplification in Daily Life (SADL) questionnaire (Cox and Alexander, 1999). The SADL is a 15-item inventory that quantifies overall (global) satisfaction, as well as a profile of satisfaction in four domains: positive effects, service and cost, negative features, and personal image.
3. *Electroacoustic evaluation of custom hearing aids.* An electroacoustic evaluation of the participant's own custom hearing aids was performed to ensure that each was functioning according to the manufacturer's specifications. The custom aids were reprogrammed to full on, and a 2-cc coupler response for a 50 dB SPL input was obtained

for each instrument. Coupler and real-ear responses were obtained using a Fonix 6500-CX Hearing Aid Test System, and the resulting data were saved in the WinCHAP 2.0 software program for later analysis. All measured 2-cc coupler responses were within ± 5 dB of manufacturer specifications from 500 to 2000 Hz. Following these measurements, the hearing aids were reset to the program the participant had been using prior to the 2-cc coupler measures.

4. *REAR and 2-cc coupler response for custom hearing aids.* With the participant's own custom hearing aids set to their normal use settings, the REAR was obtained for a wideband, speech-weighted composite test signal presented at 65 dB SPL. The hearing aid was then removed from the participant's ear and placed in the Fonix 6500-CX test box, where the 2-cc coupler output was measured for a 65 dB SPL composite signal. The WinCHAP software calculated the real-ear aided gain (REAG) and real-ear to coupler difference (RECD) responses for the custom aids.
5. *Selection of the disposable instrument tip size.* Following an otoscopic examination, a 9-mm SDHA was inserted into one ear of the participant. Maximum insertion depth was attempted, but protrusion of no greater than 5 mm from the tragus was required with patient comfort. If this could not be achieved with the 9-mm tip size, the 8- or 10-mm tip size was tried until these fit criteria were satisfied. Once an acceptable fit had been achieved for one ear, the process was repeated for the participant's other ear.
6. *Selection of the disposable instrument format and fitting.* The participant's audiogram was entered in the manufacturer-provided templates to select the initial disposable format for each ear. Using the tip size determined in the previous step, a REAR was obtained for the disposable instrument selected for each ear using a 65 dB SPL input. The REAG response was derived for each ear and was compared visually to the REAG derived for the participant's own custom-fit hearing aids. Only one of the participants had custom-fit instruments that were equipped with a volume control. In that case, the volume controls were set to the participant's normal use setting.

   Although the disposable format selected on the basis of the manufacturer templates provided a relatively close match for some participants, for others it appeared that a closer match was possible with another format providing more or less gain. In these cases, a new format was fit to the participant and the REAR repeated. Exact matches across the entire frequency range were generally not possible. Consequently, when compromises had to be made, emphasis was placed on achieving the closest possible match in the mid-frequencies.

   The disposable format providing the closest REAG match to the participant's custom-fit hearing aid in each ear was retained for use in the study. If feedback was encountered, the aid was removed and repositioned along with the probe tube of the Fonix 6500-CX. If feedback persisted and it appeared that a larger or smaller tip size might eliminate it, a different tip size (but same format) was tried. If feedback continued to be present, Comply™ wraps were used to provide a better seal using the tip size that appeared most promising. Once the feedback had been eliminated, a final REAR and RECD were measured with the selected disposable hearing aid.
7. *Objective measures of speech recognition with custom aids.* A laboratory measure of speech recognition was obtained with the participant wearing his custom-fit hearing aids, using the Hearing in Noise Test (HINT) (Nilsson et al, 1994). The HINT assesses the ability to repeat sentences in the presence of background noise. The commercially available compact disc recordings of the HINT consist of 25 10-sentence lists. Test sentences are presented in the presence of a speech-shaped noise. The competing noise was presented at a fixed level of 65 dB SPL, and the presentation level of the test sentences was adjusted adaptively in 2-dB steps until the participant could correctly repeat half of the sentences. All words of a sentence had to be repeated correctly for a sentence to be counted as correct. The level of the test sentences (in dB SPL) that yielded 50% recognition was defined as the reception threshold for sentences (RTS). Two 10-sentence lists (a total of 20 sentences) were presented to determine the RTS. Testing was performed in a sound-treated audiometric test suite following standard calibration procedures. Test materials were presented to the participant in the sound field with the test sentences presented through a loudspeaker positioned at 0-degree azimuth and the competing noise coming

from a loudspeaker positioned at 180-degree azimuth. For the one participant who was fit with custom-fit hearing aids having volume controls, the instruments were adjusted to the participant's normal use setting.

After completion of the testing described above, the participant was sent for a 2-week trial with the disposable hearing aids. He was instructed to wear only those instruments during that time. The participant was not informed that they were disposable hearing aids or of any other details about the device. Rather, they were simply described as "another hearing aid" that we wished to evaluate. The participant was instructed to wear them as much as he would wear his own custom aids and was told that he would be asked during the next visit to rate his performance with these instruments for a variety of listening situations.

The second visit was scheduled for (nominally) 2 weeks following the initial visit, although this varied according to a participant's availability. Additionally, a telephone follow-up contact was scheduled for a few days after the first visit to address any problems related to use of the disposable hearing aids that the participant might be experiencing. When problems were reported, they typically related to comfort, retention, and feedback. All were relatively minor, and, in every case, the participant agreed to continue in the study without additional adjustments to the disposable instruments.

Visit 2

During the second visit, the same dependent measures obtained with the participant's own custom-fit hearing aids during visit 1 were obtained with the disposable hearing aids. That is, the HINT, APHAB, and SADL measures were administered to the participant to assess aided speech recognition, benefit, and satisfaction, respectively. The methods of test administration of the HINT and SADL were identical to those used during visit 1. The administration of the APHAB deviated from the standard method of administration in that the two sets of APHAB ratings from the first administration (i.e., unaided and with participant's own hearing aids) were provided to the participant and the rating form included a third column in which the participant entered the ratings for the disposable hearing aids.

On completion of the testing described above, the participant was interviewed to obtain his overall impressions of the disposable instruments, including a comparison of its sound quality to that of his custom-fit hearing aids. Only after this interview was completed was the participant informed about the nature of the disposable instruments.

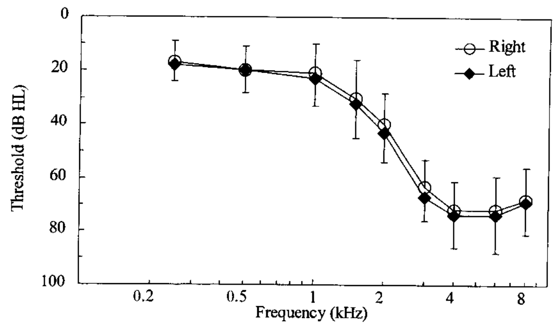

Figure 1 Mean pure-tone audiogram for the 15 participants. The error bars indicate 1 SD.

RESULTS

Participant Demographics

The 15 participants ranged in age from 36 to 68 years (mean = 54.5 years, SD = 7.5). Their mean audiogram is presented in Figure 1. Error bars, in this and all subsequent figures, indicate 1 SD. Consistent with the participant selection criteria, all had precipitously sloping ($\geq$ 35 dB from 1000 to 4000 Hz), bilaterally symmetric, high-frequency sensorineural hearing loss. Unaided monosyllabic word recognition in quiet (recorded NU-6) at a comfortable presentation level was excellent for both ears (right: mean = 93.7%, SD = 7.2; left: mean = 95.7%, SD = 6.4).

All participants were experienced users of binaural custom-fit WDRC hearing aids, ranging in experience from 3 to 13 months (mean = 7.5). The prescriptive method used during the original fitting of the custom hearing aids was either National Acoustics Laboratories-Revised or Desired Sensation Level input/output. Of the 15 participants, 13 were wearing CIC aids and 2 were wearing ITC hearing aids. Additionally, 12 of the 15 participants were using single-channel, curvilinear compression circuitry and 3 participants were wearing two-channel WDRC processors. The average daily use with their custom aids was 10.3 hours per day (range = 6 to 16+ hours).

The distribution of SDHA fittings across the 15 participants is given in Table 1. Twelve participants were fit with the same tip size and format in each ear. One participant used the

Table 1 Distribution of SDHA Fittings

SDHA Format/Tip	*Participants (n)*
S40/9 mm	5
F40/9 mm	1
Enhancer/9 mm	2
S40/10 mm	1
F40/10 mm	1
S55/10 mm	2
S40/10 mm (RE), S55/10 mm (LE)	1
F40/10 mm (RE), S40/10 mm (LE)	1
S40/8 mm (RE), S40/9 mm (LE)	1

SDHA = Songbird Disposable Hearing Aid; RE = right ear; LE = left ear.

same format in both ears but required an 8-mm tip in one ear and a 9-mm tip in the other. Two participants required different formats but used the same tip size. Participants wore the disposable hearing aids for an average of 14.0 days (range = 8 to 30 days). During this trial period, they did not have access to their own hearing aids. Mean reported hours of use of the disposable hearing aids was 9.5 hours per day (range = 6 to 16+ hours), which compared favorably with that reported for their custom-fit instruments.

REAG Matches

Figure 2 shows the mean REAG for the custom-fit hearing aids and for the disposable hearing aids providing the closest match to the participant's own hearing aids for a 65 dB SPL input signal (n = 30 ears). On average, the two functions differed relatively little, although the disposable hearing aids provide slightly greater average gain in the low- and high-frequency regions. Although these mean functions were quite similar, individual ears differed in the extent to which the closest matching disposable format approximated the response of the custom-fit instrument. Figure 3 shows the participant who yielded the best match (participant 9, right ear) and the participant for whom the poorest match was achieved (participant 6, right ear).

Comparisons of Aided Performance

Table 2 summarizes the difference scores between the custom-fit and disposable hearing aids for each dependent measure. For the HINT and APHAB, for which lower numbers indicate better performance, the score for the custom-fit hearing aids was subtracted from the score for the disposable hearing aids. For the SADL, for which higher numbers reflect greater satisfaction, the score for the disposable hearing aids was

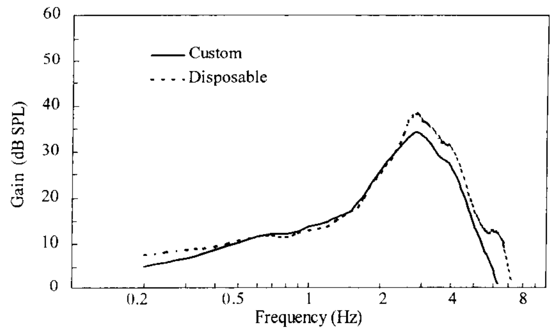

Figure 2 Mean real-ear aided gain for the custom-fit and disposable-format hearing aid providing the closest match to the patient's own hearing aids, for a 65 dB SPL input.

subtracted from the score for the custom-fit instruments. Hence, in every case, positive values indicate better performance with the custom-fit hearing aids and negative values indicate better performance with the disposable hearing aids. Difference scores that exceed the 95 percent critical difference for each measure are noted.

HINT

The mean HINT RTS scores for the custom-fit and disposable hearing aids are shown in Figure 4. These scores indicate the level of the test sentences that was required to achieve 50

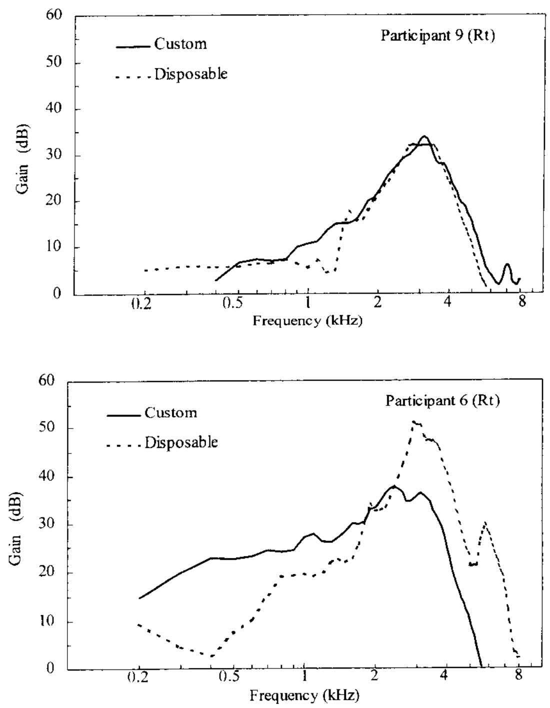

Figure 3 Real-ear aided gain for the participants who yielded the best match (participant 9) and the poorest match (participant 6).

percent correct recognition in the presence of a speech-shaped competing noise presented at 65 dB SPL. A t-test (two-tailed, correlated observations) revealed no significant difference between the two hearing aid fittings ($t = -0.25$, $p = .81$).

Although there was no significant difference in mean speech recognition in noise between the two hearing aid types, inspection of the individual participant data (see Table 2) revealed that the difference between the RTS for the custom-fit and disposable instruments exceeded the 95 percent critical difference (Nilsson et al, 1994) for 8 of the 15 participants. Of these, 4 performed better with their custom-fit hearing aids and 4 performed better with the disposable hearing aids. The remaining 7 participants performed equally well with both instrument types. Figure 5 shows the mean REAG of the custom-fit and disposable hearing aids for these three groups of participants. It is apparent that relatively close matches were achieved for all three groups. However, there was a tendency for the custom-fit hearing aids to provide slightly less gain in the lower frequencies for participants who achieved significantly better HINT performance with those instruments (panel A). Similarly, there was a tendency for the disposable hearing aids to provide slightly more gain in the higher frequencies and slightly less gain in the lower frequencies for participants who achieved significantly better HINT performance with those hearing aids (panel B). The mean audiogram for these three participant groups (averaged across right and left ears) is shown in Figure 6. Only small differences were observed in the pure-tone thresholds of the participants, according to their relative HINT scores for the two device types.

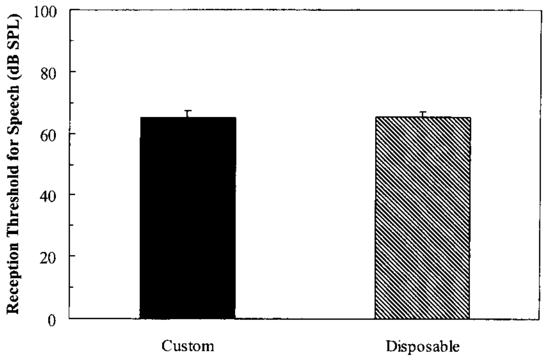

Figure 4 Hearing in Noise Test reception thresholds for sentences for the custom-fit hearing aids and the closest matching disposable-format hearing aids.

APHAB

Figure 7 shows the mean APHAB subscale scores for the participants' custom-fit and disposable hearing aids. Analysis of variance revealed that the main effect for hearing aid type was not significant ($F = 0.02$, $p = .88$). Inspection of the individual data (see Table 2) revealed that none of the participants exceeded the 95 percent critical difference (Cox and Alexander, 1995) between the two instrument

Table 2 Difference Scores between Custom-Fit Hearing Aids and Disposable Hearing Aids for Each Dependent Measure

	HINT	*APHAB*				*SADL*				
Participant	*RTS*	*EC*	*RV*	*BN*	*AV*	*PE*	*SC*	*NF*	*PI*	*Global*
1	2.8*	−1.8	0.0	0.0	0.0	−0.8	0.5	−1.4	1.0	−0.3
2	3.2*	0.0	6.0	−2.0	2.2	0.0	0.5	−0.7	0.0	0.0
3	2.9*	0.0	−6.5	4.2	−4.2	−0.7	0.0	−0.4	0.0	−0.4
4	1.7*	0.0	0.0	4.3	10.7	1.5	0.5	0.3	0.3	0.8
5	−2.0*	19.0	10.3	39.8*	−33.3	0.0	−0.5	1.0	0.3	0.2
6	−2.9*	14.8	8.2	−47.8*	−4.2	0.7	−0.5	0.7	0.3	0.4
7	1.1	0.0	0.0	0.0	−10.3	0.0	0.0	0.0	0.4	0.1
8	0.0	0.0	8.5	10.7	−2.2	−0.5	0.0	1.0	1.4	0.2
9	−1.7*	0.0	0.0	−2.2	−58.2*	−0.7	0.5	1.3	−0.7	−0.1
10	0.5	0.0	4.3	−6.5	22.5	3.0*	0.0	0.0	0.7	1.4*
11	−2.3*	19.0	35.5*	33.5*	−54.0*	3.9*	−1.0	0.0	−0.3	2.4*
12	−1.4	−12.0	−12.3	−22.8	−32.5	0.1	0.0	−0.7	0.0	−0.1
13	0.9	12.9	20.8	12.8	−8.7	4.2*	−0.5	−0.3	−0.4	1.6*
14	0.9	0.0	0.0	0.0	28.7	1.8	0.0	0.0	1.3	1.1*
15	0.5	−1.8	4.0	0.0	−5.5	3.1*	0.0	−1.4	2.0	1.5*

*Exceeds 95% critical difference.

HINT = Hearing in Noise Test; RTS = reception threshold for sentences; APHAB = Abbreviated Profile of Hearing Aid Benefit; EC = Ease of Communication; RV = Reverberation; BN = Background Noise; AV = Aversiveness; SADL = Satisfaction with Amplification in Daily Life; PE = Positive Effect; SC = Service and Cost; NF = Negative Features; PI = Personal Image.

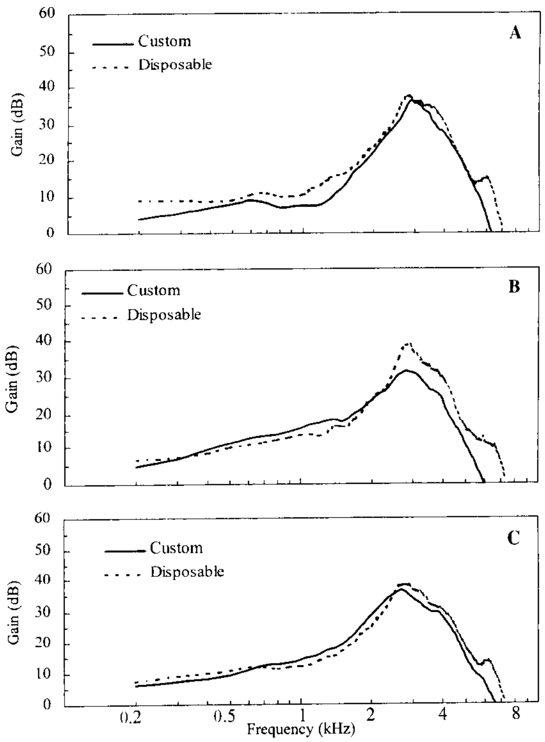

Figure 5 Mean real-ear aided gain for the custom-fit hearing aids and for the disposable-format hearing aids providing the closest match to the participant's own hearing aids, for participants who performed better on the Hearing in Noise Test (HINT) with their custom-fit hearing aids (*A*), for participants who performed better on the HINT with the disposable-format hearing aids (*B*), and for participants who did not perform significantly better on the HINT with either hearing aid type (*C*).

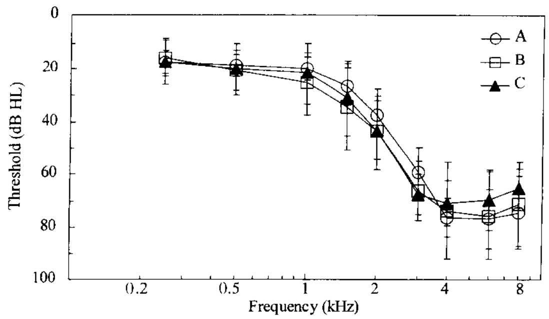

Figure 6 Mean pure-tone audiogram (averaged across right and left ears) for the participants who (A) performed better on the Hearing in Noise Test (HINT) with the custom-fit instruments, (B) performed better on the HINT with the disposable hearing aids, and (C) performed approximately the same on the HINT with both device types.

types for the Ease of Communication subscale. One participant reported significantly fewer problems understanding speech in reverberant environments with his custom-fit hearing aids than with the disposable hearing aids. For the Background Noise subscale, the critical difference was exceeded by three participants, with two reporting significantly fewer problems understanding speech in background noise with the custom-fit hearing aids and one reporting significantly fewer problems with the disposable hearing aids. Two participants reported significantly fewer problems tolerating aversive sounds with the disposable hearing aids than with their custom devices.

SADL

Figure 8 shows the mean SADL subscale and global scores for the custom-fit and disposable hearing aids. A t-test on the Global scale revealed a significant difference in overall satisfaction between the two hearing aid fittings ($t = 2.72$, $p < .05$), with the custom-fit hearing aids rated higher, on average, than the disposable hearing aids. Analysis of variance on the four subscales revealed both a significant main effect for hearing aid type ($F = 10.4$, $p < .05$) and a significant interaction of aids and subscales ($F = 3.01$, $p < .05$). T-tests on the individual subscales revealed significant differences between the two hearing aid types for Positive Effect ($t = 2.3$, $p < .05$) and Personal Image ($t = 2.2$, $p = .05$). In both cases, greater mean satisfaction was reported for the custom-fit hearing aids than for the disposable hearing aids.

Table 2 reveals that none of the participants exceeded the 95 percent critical difference (Cox and Alexander, 1999) between the custom-fit and disposable hearing aids for the Service and Cost,[1] Negative Features, and Personal Image subscales of the SADL. For the Positive Effect subscale, four participants exceeded this criterion. In every case, participants reported being more satisfied with their custom-fit instruments than with the disposable hearing aids. For the Global scale, five participants exceeded the 95 percent critical difference, with each reporting greater overall satisfaction with their custom-fit instruments than with the disposable hearing aids.

[1]Participants in this study did not pay for the disposable hearing aids. Hence, in accordance with the instructions for administering the SADL, Item 14 ("Does the cost of your hearing aids seem reasonable to you?") was deleted and the Service and Cost subscale was based only on Items 12 and 15. Similarly, the Global scale for the disposable hearing aids was based on only 14 items.

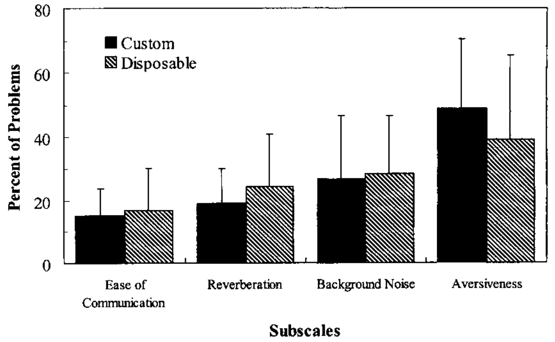

Figure 7 Mean Abbreviated Profile of Hearing Aid Benefit subscale ratings for the custom-fit and disposable-format hearing aids.

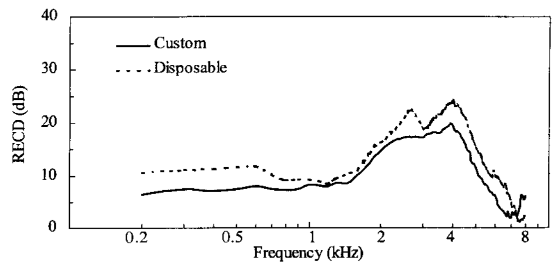

Figure 9 Mean real-ear coupler difference (RECD) (real-ear aided gain minus 2-cc coupler output) for the custom-fit and disposable-format hearing aids.

RECD

The RECD for the participants' custom-fit hearing aids and for the disposable hearing aids, averaged across the 30 ears, is presented in Figure 9. Greater mean real-ear output was provided by the disposable hearing aids than the custom-fit instruments across the frequency spectrum. The RECDs for the two hearing aid types were compared at octave and half-octave frequencies (500 to 6000 Hz) using analysis of variance. The results revealed that the difference between the mean RECD for the disposable hearing aids and custom-fit hearing aids was highly significant ($F = 20.24$, $p < .001$).

DISCUSSION

Using seven fixed electroacoustic configurations (formats) of a disposable hearing aid, reasonably close approximations to the REAR provided by the participant's custom-fit hearing aids could be achieved in most cases. The deviations observed between the REARs provided by the participants' custom-fit instruments and the closest matching disposable format did not result in a significant mean difference in objective speech recognition in a controlled laboratory test (HINT), although the difference observed for more than half of the participants exceeded the 95 percent confidence limit for repeated measures of the RTS. However, there was no consistency regarding which hearing aid type performed best. Further, the deviations between the REARs provided by the participants' custom-fit instruments and the closest matching disposable format did not result in a significant mean difference in subjective performance in everyday listening situations (APHAB), although participants tended to be significantly more satisfied in daily living (SADL) on average with their custom-fit hearing aids. These results suggest, therefore, that patients with predominantly high-frequency hearing losses who are fit with this fixed-format disposable hearing aid, in lieu of custom-fit instruments, on average, may sacrifice little in aided speech recognition or subjective benefit. However, the generally lower satisfaction ratings for the disposable hearing aids than the custom hearing aids must be considered in this context. Although satisfaction ratings (SADL) are not as direct a measure of aided performance as are the measures of aided speech recognition (HINT) and subjective aided performance in daily living (APHAB), patient satisfaction with amplification may be at least as important as these measures in determining if a patient will wear hearing aids regularly (Cox and Alexander, 1999). Recall that less mean satisfaction with the disposable hearing aids was reported for the Positive Effect and Personal Image subscales of the SADL, as well as for the Global scale. The Positive Effect subscale deals, in large measure, with psychological satisfaction with the hearing aid, whereas the Personal Image subscale deals with self-image and stigma.

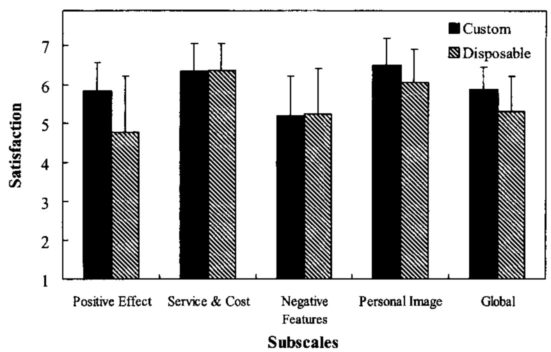

Figure 8 Mean Satisfaction with Amplification in Daily Life global and subscale scores for the custom-fit and disposable-format hearing aids.

The generally lower satisfaction ratings for the disposable hearing aids on these subscales may reflect the problems of comfort, retention, and feedback that were frequently encountered as the participants wore these instruments in daily living. Although the fitting criteria regarding comfort, maximum protrusion, and feedback could be met with every potential participant in the study at the time of the initial fitting, irritation of the ear canal, problems retaining the deep fit when talking and eating, and feedback were often encountered as the participants used the devices during the 2-week trial. These problems were never so serious that a participant asked to withdraw from the study. However, it is likely that they reduced participant satisfaction with the disposable hearing aids. This interpretation is consistent with the results of the final interviews. Participants typically reported that their ability to communicate in daily living and sound quality with the disposable hearing aids were comparable to those with their own custom-fit hearing aids. In some cases, however, negative aspects of the physical fit limited their enthusiasm for the device.

The results of this study bring into question the necessity of precise matching of hearing aid output to target prescriptions. These data suggest that a range of REAR can provide comparable aided performance to these patients. As long as comparable spectral regions are made sufficiently audible and uncomfortable loudness is avoided, there may be a relatively broad range of frequency-gain responses that will suffice. This conclusion is consistent with the findings of other investigators. Humes (1986), for example, evaluated 10 prescriptive methods and determined that articulation index–predicted speech recognition did not differ significantly among the procedures. Similarly, Sullivan and colleagues (1988) compared four prescriptive methods using a master hearing aid. Only small differences in speech recognition were observed among the four procedures at comfortable listening levels. Humes and Hackett (1990) compared gain and speech recognition performance for hearing aids selected using three prescriptive methods in routine clinical use. Significant differences existed among the gain/frequency responses prescribed to their participants by the three prescriptive methods. Nevertheless, no significant differences were observed in aided speech recognition performance.

The results of the RECD measurements revealed that the disposable hearing aids provided consistently greater gain at the tympanic membrane than did the participants' custom-fit instruments for a given amount of coupler gain, most notably in the higher frequencies. This finding is consistent with those reported by Cook and Preves (2001) for the same disposable instrument. Presumably, the greater RECD observed for this hearing aid was attributable to its generally deeper insertion into the external canal than was typical of most of the custom fittings. A more shallow insertion would not provide this advantage. In this regard, it is important to note that although the disposable instrument could be fit to most ears using one of the three available tip sizes, retention of the deep insertion was a problem in some patients. The device gradually worked its way out after several hours of use and caused irritation in the canal. For this reason, a less deep fitting of the device in the external canal is often achieved in routine clinical use (JA Cook, personal communication, February 22, 2002). In such cases, the RECD could be reduced significantly and, in some cases, could influence the disposable format that would be most appropriate for a patient.

Retention and irritation in the external canal were problems encountered by several participants and were clinically challenging and time consuming to resolve. In addition, feedback was a problem with some patients. Comply wraps were required in 9 of the 15 participants (13 of the 30 ears) to eliminate feedback problems, regardless of the tip size. The problems frequently encountered when fitting disposable hearing aids (i.e., without a custom-fit mold) have been reported previously (Sweetow, 2001a). Further, Fabry (2001) and Sweetow (2001b), reporting their experiences fitting the SDHA, indicated that patients obtain good sound quality and performance with the device. However, both encountered patient discomfort and feedback problems with some patients (DA Fabry, personal communication, April 21, 2001).

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