Purpose: To determine whether listeners with primarily high-frequency sensorineural hearing loss (HF SNHL) perceived benefit from amplification provided by completely-in-the-canal (CIC) hearing aids.

Method: The Hearing Handicap for the Elderly—Screening version, the Abbreviated Profile of Hearing Aid Benefit, and the Satisfaction With Amplification in Daily Life questionnaires were mailed to 2 groups of listeners (n = 79) who matched preset criteria, including threshold at 2000 Hz and use of CIC amplification. Sixty-seven percent (n = 53) of the questionnaires were returned and were divided into 2 groups. Group I (n = 26) consisted of listeners with normal hearing through 2000 Hz, and Group II (n = 27) consisted of listeners with normal hearing only through 1000 Hz.

Results: Results revealed that both groups perceived significant hearing handicap, hearing aid benefit, and hearing aid satisfaction. Differences between the 2 groups on the 3 measures, however, were not statistically significant.

Conclusions: Listeners with HF SNHL perceived benefit and satisfaction from amplification with CIC hearing aids. Individuals with SNHL limited to the high frequencies should be considered candidates for amplification.

Key Words: hearing aid benefit, hearing aid outcomes, high-frequency hearing loss
practical options for fitting strictly high-frequency hearing losses. For instance, completely-in-the-canal (CIC) hearing aids provide several advantages over in-the-ear hearing instruments for listeners with HF SNHL, including (a) a potential reduction of the occlusion effect, depending on the depth of the fit in the ear canal (Chung, 2004; Mueller, 1994); (b) less gain requirements due to increased sound pressure level at the tympanic membrane (Chasin, 1994); and (c) use of natural pinna effects (Agnew, 1994; Chasin, 1994). More recently, open-canal behind-the-ear (BTE) hearing aids have been introduced to the market (Mueller, 2006). Open-canal BTEs consist of a BTE housing attached to a thin tube with an open ear tip that inserts deep into the ear canal. This style of hearing aid also works particularly well for high-frequency hearing losses. The open ear tip seated deep in the ear canal delivers the amplified sound without occluding the ear canal. Therefore, this style allows the provision of needed high-frequency amplification without overamplification of low-frequency energy where hearing sensitivity is often within the normal range.

Both CIC and open-canal BTE hearing aids are good amplification options for listeners with HF SNHL. The evidence regarding the provision of high-frequency audibility to improve speech recognition, however, is not as clear. Some studies suggest that improving the audibility of high-frequency speech energy (i.e., above 3000 Hz) does not result in improved speech recognition (Hogan & Turner, 1998; Turner & Cummings, 1999). Specifically, both Hogan and Turner (1998) and Turner and Cummings (1999) found a lack of improvement in nonsense syllable recognition when their listeners were provided with audible high-frequency speech energy, particularly when the hearing loss exceeded 55 dB HL. The lack of benefit found in these studies is confounded by at least two factors: (a) speech recognition performance was measured in quiet, and (b) the high-frequency speech energy was made audible by increasing the level of the entire speech signal. First, speech recognition performance measured in quiet is often insensitive to the effects of hearing loss. On the other hand, studies that have measured the benefits of high-frequency audibility on speech recognition in noise have consistently found improvements in listeners with HF SNHL (Hornsby & Ricketts, 2003; Pleyer & Fleck, 2006; Turner & Henry, 2002). For example, Pleyer and Fleck (2006) studied speech recognition in quiet and noise in a group of listeners with HF SNHL fit with CIC hearing aids. Speech recognition was measured under two amplification schemes: minimal high-frequency amplification and maximum high-frequency amplification. In the quiet condition, performance between the two amplification schemes was equivocal. The noise condition, however, resulted in significantly better recognition performance in the maximum high-frequency scheme compared to the minimum high-frequency scheme. Second, by increasing the level of the entire speech signal, low-frequency energy is amplified unnecessarily and may mask important high-frequency speech information (Cook et al., 1997). When the frequency response of the signal is manipulated to amplify only the high-frequency region (e.g., aided listening), listeners with HF SNHL exhibit substantial improvements in speech recognition (Lee et al., 1993; Pleyer & Fleck, 2006; Schwartz, Surr, Montgomery, Prosek, & Walden, 1979; Sullivan et al., 1992; von Buchwald, Pedersen, & Parving, 1991). Taken together, the results of these studies suggest that high-frequency audibility does benefit listeners with HF SNHL, particularly when listening to a speech signal degraded by a background competitor.

Prior to the availability of open-fit BTE hearing aids, one of the few amplification options available to these patients was CIC hearing aids. Even with the availability of the open-fit BTEs and the clear market trend toward open fittings (Nemes, 2008), CICs are still an appropriate and viable option for HF SNHL. The Audiology Clinic at the VA Medical Center in Mountain Home, TN, has a large patient base with HF SNHL above 2000 Hz due to military-related noise exposure. Many of these patients have been fit with CIC hearing aids. Given that listeners with HF SNHL do experience communication difficulties and there is some evidence suggesting the limited benefit of high-frequency audibility, it is important to determine the efficacy of CIC fittings in these listeners. Specifically, do listeners with high-frequency hearing loss perceive (a) a hearing handicap, (b) hearing aid benefit, and (c) hearing aid satisfaction? If so, do listeners with hearing loss limited to frequencies above 2000 Hz differ in perceived hearing handicap, benefit, and satisfaction from listeners with hearing loss above 1000 Hz? The primary purpose of the present study was to determine unaided hearing handicap, perceived hearing aid benefit, and perceived hearing aid satisfaction for two groups of listeners with HF SNHL who differed in the frequency at which their hearing loss began: one group of listeners with normal hearing through 2000 Hz, and one group of listeners with normal hearing only through 1000 Hz. A secondary purpose was to determine differences, if any, in hearing handicap, hearing aid benefit, and hearing aid satisfaction between the two groups of listeners.

**Method**

**Participants**

Potential veteran participants with HF SNHL were identified through patient records from the Audiology Clinic at the VA Medical Center in Mountain Home. Seventy-nine male veterans were identified who met the following selection criteria: pure-tone thresholds no greater than 30 dB HL for frequencies of 250–1000 Hz, symmetric SNHLs with no more than a 10-dB difference in thresholds at any frequency, and binaural CIC hearing aid fittings within the last 4 years. CIC fittings were chosen for several reasons, including (a) consistency in hearing aid style thereby minimizing variability among participants; (b) the majority of listeners fit with CICs have near normal low- to mid-frequency hearing sensitivity; and (c) CICs offer advantages for high-frequency hearing loss fittings (Agnew, 1994).

A total of 53 participants returned the questionnaires. Group I consisted of 26 participants ranging in age from 38 to 75 years ($M = 53$). Group II consisted of 27 participants ranging in age from 51 to 79 years ($M = 63$). Figure 1 presents mean pure-tone thresholds and standard deviations for Groups I and II combined across ears. Table 1 presents mean age and audiometric data for Groups I and II. As can be seen in Figure 1 and in Table 1, both groups exhibited, on
average, a moderate to moderately severe high-frequency SNHL. The primary difference between the two groups was their threshold at 2000 Hz. Specifically, Group I participants were limited to thresholds at or below 30 dB HL at 2000 Hz, while Group II participants were limited to thresholds at or above 40 dB HL at 2000 Hz. A single-factor analysis of variance (ANOVA) confirmed that the mean threshold at 2000 Hz of Group II was significantly higher than the mean threshold of Group I, $F(1, 51) = 4.03, p > .001$. Also noticeable from Table 1 is the difference in mean age between Groups I and II (52.3 and 64.3 years, respectively). Indeed, a single-factor ANOVA confirmed that Group II was significantly older than Group I, $F(1, 51) = 31.6, p < .001$.

All participants had been fit with digitally programmable CIC hearing aids with analog circuitry and either input or output limiting compression. All hearing aids were fit according to the same clinic protocol, which consisted of fitting the instrument past the second bend of the ear canal, and functional gain verification to a National Acoustics Laboratories-Revised (NAL-R) target. Functional gain values were considered to be acceptable if they were $\pm 3$ dB at 250–3000 Hz, and were $\pm 5$ dB at 4000 Hz and above. Table 2 presents a profile of respondents for Groups I and II that was generated from secondary information provided by the Abbreviated Profile of Hearing Aid Benefit (APHAB; Cox & Alexander, 1995) and Satisfaction With Amplification in Daily Life (SADL; Cox & Alexander, 1999), specifically hearing aid experience, daily hearing aid use, and employment status. All participants had a minimum of 6 weeks of experience with their CIC hearing aids, with the majority of listeners (66%) having at least 1 year of experience with amplification. All respondents reported wearing their hearing aids on a daily basis, with the majority (76%) wearing their hearing aids between 1 and 8 hr per day (see Table 2). Fifteen percent of the respondents reported wearing their hearing aids less than 1 hr per day. Similarly, 8% reported wearing their hearing aids less than 8 hr per day.

**Profile of Nonrespondents**

Twenty-six veterans did not respond to the questionnaires: 10 from Group I and 16 from Group II. A random sample of the nonrespondents ($n = 14$) were interviewed by telephone and were asked a series of questions in order to develop a profile:

1. Did you receive the questionnaires?
2. Are you currently wearing your hearing aids?
3. Why didn’t you return the questionnaires?

All participants interviewed received the questionnaires. The majority of nonrespondents interviewed stated that they did not wish to participate in the study. A summary of responses to Questions 2 and 3 for each group is presented in Table 3.

![Figure 1. Mean pure-tone thresholds for Group I and Group II collapsed across ears. Standard deviations are presented as error bars for each frequency.](image)

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### Table 1. Means, standard deviations, and ranges for age, word recognition scores in quiet, and hearing thresholds (dB HL) for Groups I and II.

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Word recognition (% correct)</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RE</td>
<td>LE</td>
</tr>
<tr>
<td>I</td>
<td>M</td>
<td>52.3</td>
<td>90.8</td>
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<tr>
<td></td>
<td>SD</td>
<td>7.9</td>
<td>7.6</td>
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<tr>
<td>II</td>
<td>M</td>
<td>64.3</td>
<td>78.6</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>7.6</td>
<td>15.6</td>
</tr>
</tbody>
</table>

**Note.** Data for hearing thresholds are collapsed across right (RE) and left ears (LE). Word recognition was measured using the NU-6 (Northwestern University Auditory Test No. 6).
Three questionnaires were used to measure unaided hearing handicap, perceived hearing aid benefit, and hearing aid satisfaction: the Hearing Handicap Inventory for the Elderly—Screening version (HHIE–S; Ventry & Weinstein, 1983), the APHAB (Cox & Alexander, 1995), and the SADL (Cox & Alexander, 1999). The HHIE–S is a 10-item inventory designed to assess perceived handicap associated with hearing loss and addresses the consequences of hearing loss on daily life. A score of ≥10 on a scale from 1 to 40 indicates at least a mild-to-moderate hearing handicap (American Speech-Language-Hearing Association, 1997; Lichtenstein, Bess, & Logan, 1988).

The APHAB is a 24-item inventory designed to quantify perceived hearing aid benefit by comparing unaided and aided responses to statements regarding different listening environments. The APHAB assesses multiple listening environments (i.e., subscales) that include Ease of Communication, Reverberation, Background Noise, and Aversiveness of Sounds. A difference of ≥22 between the unaided and aided APHAB subscale scores indicates that the listener perceives benefit from amplification (Cox & Alexander, 1995). Lastly, the SADL is a 15-item inventory designed to assess satisfaction with amplification. The SADL produces a global satisfaction score on a 1–7 scale, with a score of 1 being the least satisfied and a score of 7 being the most satisfied with amplification.

**Procedures**

The three questionnaires (HHIE–S, APHAB, and SADL) were mailed to each patient identified (n = 79). Once a 50% response rate was achieved, the questionnaires were mailed a second time to those who did not respond to the first mailing. The final response rate was 67% (n = 53/79). Participants were instructed to complete the questionnaires as follows: (a) HHIE–S was completed according to unaided listening; (b) the APHAB was completed for both unaided and aided listening (thus generating benefit scores); and (c) the SADL was completed for aided listening.

**Results**

Individual scores for each of the questionnaires were determined according to the standardized instructions (Cox & Alexander, 1995, 1999; Ventry & Weinstein, 1983). Scores for the SADL, however, were adjusted by excluding Question 14, “Does the cost of your hearing aid seem reasonable to you?” The veterans who participated in the present study did not pay for their hearing aids; therefore, it would be inappropriate to include the question regarding cost. Means and standard deviations for the HHIE–S, APHAB, and SADL are presented in Figures 2–4, respectively. The figures show the means and standard deviations for each group and each questionnaire. Specifically for the APHAB, mean benefit scores are displayed according to APHAB categories: Emotional, Social, and Total. Standard deviations are presented as error bars.

Figure 2. Mean scores of the Hearing Handicap Inventory for the Elderly—Screening Version (HHIE–S) for Groups I and II. Means are displayed according to HHIE–S categories: Emotional, Social, and Total. Standard deviations are presented as error bars.
scores are plotted and were derived from the difference between the unaided and aided responses. Table 4 presents mean APHAB scores for each subscale for each condition: unaided, aided, and derived benefit scores. As can be seen in Figure 1, mean scores from the HHIE–S indicated a significant hearing handicap (scores of ≥10) for both Groups I and II. Similarly, mean scores for Groups I and II on the APHAB and the SADL indicate perceived benefit and satisfaction with hearing aids based on the criteria established for each measure (e.g., Cox & Alexander, 1995, 1999; see Figures 3 and 4).

The data were further examined using a single-factor ANOVA to compare differences between the two groups on each measure. The ANOVAs indicated that there were no significant differences between Groups I and II in perceived hearing aid benefit—APHAB subscales: Ease of Communication, $F(1, 51) = 0.21, p > .05$, Reverberation, $F(1, 50) = 0.05, p > .05$, Background Noise, $F(1, 49) = 0.28, p > .05$, and Aversiveness of Sounds, $F(1, 50) = 0.26, p > .05$—hearing aid satisfaction (SADL), $F(1, 50) = 0.08, p > .05$, and unaided hearing handicap (HHIE–S), $F(1, 51) = 2.99, p > .05$. A few questionnaires were returned incomplete. Therefore, there were some missing data points for a few of the analyses.

Discussion

The primary purpose of the present study was to determine hearing aid outcomes, including hearing handicap, hearing aid benefit, and hearing aid satisfaction for listeners with HF SNHL limited to frequencies above 2000 Hz fit with CIC hearing aids. Given that listeners with hearing loss limited to the high frequencies (>2000 Hz) are often considered borderline candidates for amplification (Mueller et al., 1991; Van Vleit, 1999), it was of interest to know whether these listeners perceive hearing difficulties (e.g., a hearing handicap). According to Lichtenstein et al. (1988), a score of ≥8 on the HHIE–S indicates at least mild hearing handicap. Results from the HHIE–S indicated that, on average, listeners from both Groups I and II perceived hearing difficulties (e.g., a hearing handicap). The amount of hearing handicap reported, however, was not significantly different between groups. This suggests that
listeners with hearing loss limited to frequencies above 2000 Hz (Group I) experience listening difficulties not readily apparent from their speech recognition scores. As seen in Table 1, word recognition scores in quiet for Group I were on average 90% for both ears. Further inspection of the HHIE–S questionnaires revealed that the majority of listeners (85%) reported a noisy situation to be handicapping. Indeed, 89% and 81% of listeners from Groups I and II, respectively, answered either “yes” or “sometimes” to the question “Does a hearing problem cause you difficulty when in a restaurant with relatives or friends?” This question directly refers to a listening environment in which background noise is likely to be present. The results from this question support the conclusion that listeners with HF SNHL may experience speech recognition deficits in a competing background, although little to no difficulty is exhibited in quiet. Research that directly measures speech recognition in a competing background for listeners with HF SNHL, however, is needed.

It was also of interest to know whether listeners with HF SNHL perceive benefit from amplification. The evidence regarding the provision of high-frequency audibility to improve speech recognition is somewhat contradictory. For example, studies have suggested that high-frequency amplification would not benefit listeners with hearing thresholds greater than 50 dB HL above 2000 Hz (Hogan & Turner, 1998; Turner & Cummings, 1999). Specifically, Turner and Cummings (1999) found that listeners with thresholds greater than 55 dB HL did not exhibit improvements in nonsenselable recognition in quiet when provided with high-frequency audibility. Although Turner and Cummings provided high-frequency audibility to their listeners, that audibility was established by increasing the level of the entire speech signal. On the other hand, when the high-frequency portion of the speech signal is made audible through manipulation of the frequency response (i.e., aided listening), listeners with high-frequency hearing loss have shown significant improvements in speech recognition performance relative to the unaided condition (Hornsby & Ricketts, 2003; Flyer & Fleck, 2006; Schwartz et al., 1979; Sullivan et al., 1992; Turner & Henry, 2002). APHAB results from the present study indicate that listeners with SNHL at and above 2000 Hz do perceive benefit from amplification when listening in quiet, in background noise, and in reverberation. On the other hand, both groups reported a lack of benefit for the Aversiveness of Sounds subscale, consistent with previous research (Cox & Alexander, 1995). This result indicates that both groups have a reduced tolerance to environmental sounds, perhaps reflecting a reduced dynamic range. Overall, both groups from the present study exhibited mean benefit scores ≥22, meeting the criteria established by Cox and Alexander (1995) that indicates a substantial difference between unaided and aided listening conditions.

The results of the APHAB are consistent with previous studies reporting hearing aid benefit in listeners with HF SNHL (Beamer et al., 2000; Bennett, 1989; Orchik, Cowgill, & Parmely, 1990). Bennett (1989) interviewed aided listeners with minimal hearing loss through 2000 Hz (≤35 dB HL) and found that the majority of listeners perceived benefit from amplification in home, work, and social situations. Orchik et al. (1990) also presented a case in which a listener with normal hearing through 2000 Hz fit with CIC hearing aids reported perceived benefit from amplification, especially in crowds. The same listener also demonstrated a 20% improvement (76% to 96%) in speech recognition performance at a signal-to-noise ratio (SNR) of +10 dB between unaided and aided conditions. The improvement in speech recognition performance is not surprising given that a +10 dB SNR is relatively advantageous to the listener. Most recently, Beamer et al. (2000) investigated perceived hearing aid benefit based on the Profile of Hearing Aid Benefit (Cox & Gilmore, 1990) in a group of listeners with SNHL above 2000 Hz fit with hearing aids through the Walter Reed Army Medical Center. Although the styles of hearing aids (e.g., in-the-ear and BTE) differed from the present study (CIC), significant benefit scores were reported (Beamer et al., 2000). Taken together, the above results suggest that predominately high-frequency amplification may be beneficial for listeners with HF SNHL.

In addition to the question of hearing aid benefit, the present study asked whether listeners were satisfied with their present hearing aids. The question of hearing aid satisfaction was based on the global score provided by the SADL. Initial data from Cox and Alexander (1999) suggest a score of 4.9 on a scale from 1 to 7 (with 7 being the most satisfied) as a norm. Both Groups I and II from the present study had mean satisfaction scores of 5.1 and 5.2, respectively. The mean scores are similar to that of Cox and Alexander (1999), indicating satisfaction with their hearing aids. A potential bias exists regarding the SADL data in that the veteran patients from the present study received their hearing aids at no cost. Although the SADL accounts for this in the overall score through removal of the question regarding cost, listeners who do not pay for their hearing aids tend to report more satisfaction than do listeners who purchase their hearing aids (Cox & Alexander, 1999).

A secondary question of the present study was whether listeners with HF SNHL above 2000 Hz differed in perceived hearing handicap, hearing aid satisfaction, and hearing aid benefit from listeners with HF SNHL above 1000 Hz. Analysis of the results did not reveal any significant differences between the two groups for the three measures (i.e., SADL, HHIE–S, and APHAB). The lack of significant differences between groups on any of the measures indicates that the groups are very similar in self-reported hearing handicap, hearing aid satisfaction, and hearing aid benefit, despite a mean difference of 31.2 dB HL in hearing sensitivity at 2000 Hz. The above similarities among Groups I and II suggest that the threshold at 2000 Hz alone may not be a critical factor in a successful hearing aid fitting. These results and conclusions, however, should be taken with caution given the significant age differences between the two groups. Group selection was based primarily on degree and configuration of hearing loss, as well as use of CIC hearing aids. Age, however, was not controlled as a variable. Given the lack of significant differences between the two groups on any test measure, it is unlikely that age had an effect.

The threshold at 2000 Hz alone may not be a critical factor; however, listeners with near normal hearing through 2000 Hz may require extra counseling when considering amplification. This point is illustrated when considering the reported hearing aid usage between the respondents and
nonrespondents. All respondents from Groups I and II reported wearing their hearing aids, with the majority (76%) reporting usage between 1 and 8 hr per day (26% 1–4 hr/day, 49% 4–8 hr/day). On the other hand, almost half (43%) of the nonrespondents interviewed reported that they do not wear their hearing aids (see Table 3). Five of the 6 listeners who reported that they do not wear their hearing aids had hearing loss above 2000 Hz. In these instances, the hearing aid fitting was either unsuccessful or the individual’s listening needs changed over time. Further counseling at the initial hearing evaluation may have indicated other possible reasons why these listeners were not potential amplification candidates. A small percentage (15%) of the respondents reported that they were wearing their hearing aids less than 1 hr per day. Further inspection of the data indicated that all but one of these listeners was retired. One conclusion may be that these retired individuals encounter fewer demanding listening situations than more active listeners. Similarly, further counseling of these listeners may have indicated their lack of amplification needs.

Results of the present study indicate that patients with HF SNHL perceive benefit and satisfaction from amplification with CIC hearing aids. Individuals with HF SNHL should therefore be considered potential candidates for amplification. CIC hearing instruments are a viable choice due to the advantages offered by this style of hearing aid, particularly the increase in high-frequency amplification due to the placement of the microphone in the ear canal and the potential for fewer problems related to the occlusion effect. The results of the present study, however, should be taken with caution due to the large variability associated with both groups, particularly on the APHAB benefit measures. This variability emphasizes the importance of appropriate counseling and follow-up when fitting listeners with HF SNHL, particularly regarding realistic hearing aid expectations. Further research is needed to determine the effect of threshold at 2000 Hz on both unaided and aided speech recognition in noise measures for listeners with HF SNHL.

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