Hearing Aid Use, Central Auditory Disorder, and Hearing Handicap in Elderly Persons

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James Jerger*

Abstract
We compared self-reported handicap (Hearing Handicap Inventory for the Elderly, HHIE) scores before and after a 6-week period of hearing aid use in subjects drawn from a pool of 115 elderly persons with hearing impairment. Study patients (PTs) were divided into two categories according to whether scores on a dichotic listening test (Dichotic Sentence Identification Test, DSI) were normal or abnormal. In a subgroup of 63 persons who had not previously used amplification, subjects in the two DSI categories showed equivalent average HHIE scores. After 6 weeks of first-time hearing aid use, there was a significant improvement in average HHIE scores, but only in the DSI-normal category. In the subgroup with dichotic deficits (DSI-abnormal group), average HHIE scores did not change significantly after hearing aid use. In a subgroup of 89 PTs, we compared the self-assessed HHIE scores of the PTs with the HHIE scores rated by their significant others (SOs). In both DSI categories, the average handicap, as judged by the subject's SO, was significantly greater than the handicap as judged by the PT. In addition, both ratings reflected significant improvement after hearing aid use. It was the case, however, that improvement consequent on amplification was significantly smaller for subjects in the DSI-abnormal category. Finally, we show, in the entire pool of 115 PTs, that the effect of practice on the HHIE score is not sufficient to explain the improvement after amplification. Results affirm both the positive value of amplification and the negative impact of central auditory deficit as they affect the HHIE scores of the elderly hearing-impaired person.

Key Words: Aging, central auditory deficit, dichotic, hearing aids, hearing handicap, presbyacusis

Abbreviations: DSI = dichotic sentence identification, FR = free report, DR = directed report, HA = hearing aid, HHIE = Hearing Handicap Inventory for the Elderly, PTA, = average of the HTLs at 500, 1000, and 200 Hz, PTA, = average of the HTLs at 1000, 2000, and 4000 Hz, PT = study patient, SO = study patient's significant other, MMSE = Mini-mental Status Examination, CVLT = California Verbal Learning Test, TSAT = Timed Sustained Attention Test, DSSI = Duke Social Support Index

The hearing problems of the elderly cannot be predicted solely from the degree of peripheral hearing sensitivity loss. Instead, these problems seem to reflect both peripheral and central components. In addition to the long-recognized and well-documented age-related decline in pure-tone sensitivity, elderly persons also seem to show changes in central auditory processing (Bergman, 1971; Bergman et al, 1976; Konkle et al, 1977; Welsh et al, 1985; Jerger et al, 1989, 1990a; Jerger, 1992). Recent evidence suggests that such central auditory processing disorders can adversely affect the self-assessed handicap of the hearing-impaired person. Jerger et al (1990b), for example, found that subjects with evidence of central deficits reported more hearing handicap than subjects without central deficits. Moreover, significant handicap was reported by some central-deficit patients who had only relatively mild degrees of peripheral hearing loss.

Of further relevance to these issues is the social milieu in which the elderly person with hearing impairment may reside. How, for example, does the patient's significant other (spouse,
fiance, friend, etc.) assess the handicapping effect of the auditory disorder? In a previous communication (Chmiel and Jerger, 1993) concerned with the self-assessment of handicap by means of the Hearing Handicap Inventory for the Elderly (HHIE) (Ventry and Weinstein, 1982), we showed that elderly persons with hearing impairment tended to rate themselves as less handicapped than did their significant others (SOs). The difference was not affected by degree of loss but was affected by slope of loss and by the presence of central auditory processing disorder.

The extent to which the use of conventional hearing aids impacts quality of life in the hearing impaired has also been subjected to substantial quantitative analysis (Birk-Nielsen and Ewertsen, 1974; Salomon et al, 1988; Malinoff and Weinstein, 1989; Mulrow et al, 1990b). Mulrow et al (1990b) reported that hearing aids successfully reduced the social, emotional, and communication dysfunctions reported by elderly veterans. Weinstein (1991) also concluded that interference with psychosocial well-being can be temporary if rehabilitation services, including hearing aids, are provided to hearing-impaired elderly persons.

Elderly individuals seem less satisfied with hearing aids than younger persons (Jerger and Hayes, 1976; Berger and Hagberg, 1982; Smedley, 1990). Only 10 to 25 percent of elderly hearing-impaired individuals own hearing aids (Dodds and Harford, 1982; Schow, 1982; Goldstein, 1984; Lee et al, 1991; Ward et al, 1993), and only 30 to 50 percent of the elderly who own hearing aids use them regularly (Sorri et al, 1984; Ward et al, 1993). Although a number of extra-auditory problems (e.g., cognitive decline) may reduce successful hearing aid use, a significant factor contributing to dissatisfaction with hearing aids seems to be the presence of central auditory processing disorder (McCandless and Parkin, 1979; Stach et al, 1990, 1991).

In general, the complex interaction between impaired peripheral and central auditory mechanisms has not been carefully considered in studies assessing quality of life in the elderly. The majority of studies have concentrated solely on the effects of peripheral hearing loss (Herbst and Humphrey, 1980; Salomon et al, 1988; Malinoff and Weinstein, 1989; Mulrow et al, 1990a). In the present study, we investigate, in elderly hearing-impaired persons, the extent to which the presence of central deficit affects the reduction of self-assessed handicap by the use of hearing-aid amplification, the extent to which the self-assessed handicap of the elderly person differs from the handicap rated by the elderly person’s SO, and the extent to which the assessment of the handicap by the SO is influenced by such central auditory disorder.

**METHOD**

**Subjects**

Study patients (PTs) were 115 elderly individuals and their SOs. Table 1 summarizes the demographic characteristics of the study group, including data on educational attainment, financial adequacy, comorbid conditions, medications, and degree of hearing sensitivity loss. All subjects were paid volunteers recruited from community centers throughout the Houston metropolitan area. They responded to an advertisement offering evaluation of hearing status and the opportunity to sample various amplification alternatives. The specific inclusion criteria were as follows:

1. Age greater than 60 years.
2. High-frequency loss (pure-tone average [PTA]; average of the hearing threshold

<table>
<thead>
<tr>
<th>Table 1 Demographic Characteristics for a Sample of 115 Elderly Hearing-Impaired Subjects</th>
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<tbody>
<tr>
<td>Demographic Characteristics</td>
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<tr>
<td>Men</td>
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<td>Women</td>
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<td>Age (yr)</td>
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<td>Married</td>
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<td>Retirees</td>
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<tr>
<td>Education</td>
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<td>High school diploma or GED</td>
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<td>Some college</td>
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<td>College degree</td>
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<td>Graduate school/professional</td>
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<td>Financial adequacy (how well money takes care of needs)</td>
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<tr>
<td>Very well</td>
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<td>Fairly well</td>
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<td>Poorly</td>
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<td>Clinical Characteristics</td>
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<tr>
<td>Comorbid conditions*</td>
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<td>Medications†</td>
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<td>Hearing loss</td>
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<td>PTA₃</td>
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<td>PTA₄</td>
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</table>

*Average number of diagnosed medical conditions for subjects; †average number of prescribed medicines taken by subjects; ‡mean PTA in dB HL of 500, 1000, and 2000 Hz averaged across ears; and §mean PTA in dB HL of 1000, 2000, and 4000 Hz averaged across ears.
levels [HTLs] at 1000, 2000, and 4000 Hz) greater than 25 dB in both ears.

3. Interaural sensitivity difference (PTA; average of the HTLs at 500, 1000, and 2000 Hz) less than 20 dB.

4. Normal middle ear status by immittance audiometry.

5. Average score of 3 or less on a 5-point, self-report scale of physical health. The scale ranged from 1 (excellent) to 5 (very poor). The overall rating was based on questions relating to current health status, eyesight, extent to which daily life was limited by the PT's state of health, how many days the PT had been sick, and how often the PT had visited a physician during the 6-month period prior to the study.

6. A score of 24 or more on the Mini-Mental State Exam (MMSE; Folstein et al., 1975).

7. No previous history of neurologic or psychiatric disorder.

Experimental Conditions

The data reported in this paper were obtained as part of a larger study comparing the relative merits of conventionally worn, behind-the-ear hearing aids, assistive listening devices with remote microphones, and a combination of the two amplification systems. Over the course of 6 months, PTs actually participated in a baseline condition and four treatment conditions: (1) hearing aid alone (HA), (2) assistive listening device alone (ALD), (3) HA + ALD, and (4) no amplification (no HA). Each treatment condition lasted 6 weeks. The order in which each PT participated in each condition was random. In the present paper, we report only the results of two conditions, baseline and HA, since our purpose was to examine the effect of the use of a conventionally worn, behind-the-ear hearing aid on perceived handicap. Subsequent papers will compare results obtained across the full range of treatment conditions.

For the HA condition, PTs were fit monaurally with either a Siemens Triton 3000 or a 3M Memory Mate digital/analog hybrid instrument. We chose to confine the study to monaural, as opposed to binaural, fitting in order to maintain comparability with the ALD and ALD + HA conditions, which were, of necessity, monaural conditions.

The ear to be aided was selected at random. The choice of hearing aid was based on audiometric configuration. PTs with relatively milder losses and little or no low-frequency loss were fit with the 3M memory mate aid. PTs with relatively greater low-frequency losses were fit with the Siemens Triton 3000. Hearing aids were fit using a Virtual Model 340 Real-Ear Measurement System coupled to a Danplex Programmable Multi-Channel (PMC) System. The PMC system allows for the adjustment of several digitally programmable hearing aids by using interchangeable software modules inserted into a single programming unit. From the pure-tone audiometric data, the desired frequency response of the hearing aid was determined using the National Acoustic Laboratories' (NAL) procedure (Byrne and Dillon, 1986). Real-ear insertion gain measurements were obtained unaided and with the hearing aid coupled to the system. Then, a computer algorithm was initiated, which provided an estimate of the best fit of the gain and frequency response of the hearing aid to the NAL target. The hearing aid was adjusted until the frequency response matched as closely as possible the NAL target response.

Test Sessions

PTs participated in six test sessions. Test Session 1, lasting approximately 1 hour, consisted of the measurement of peripheral hearing loss by conventional pure-tone audiometry and a series of screening measures of vision, physical health, and mental status to determine whether subjects met the criteria for the study. If all subject criteria were met, an earmold impression was made and the remaining five visits were scheduled.

During Test Session 2, a battery of tests was administered to establish central auditory status, neuropsychological status, and self-assessed handicap. The test procedures during this session were divided into two categories: subject descriptors and outcome measures. Subject descriptors were used to describe the hearing loss, cognitive status, and personality or social factors associated with use of amplification. The outcome measure, the HHIE, was used specifically to compare performance after each of the experimental conditions. Thus, the outcome measure (HHIE) obtained during Test Session 2 was considered the baseline or pretreatment measure. Test Session 2 lasted approximately 2.5 hours. Following Test Session 2, the PT began one of the four treatment conditions (HA, ALD, HA + ALD or no HA).

During Test Sessions 3, 4, and 5, and 6, scheduled 6 weeks apart, the HHIE was repeated.
Subject Descriptors

Neuropsychological Measures

Personality. The NEO Five-Factor Inventory (NEO-FFI), standardized on adults from 20 to 90 years, was used to measure the 5 domains of personality: (1) neuroticism, (2) extraversion, (3) obsessiveness, (4) agreeableness, and (5) compulsiveness (Costa and McCrae, 1986). Subjects completed a self-report version of the instrument that included 60 items scored on a 5-point Likert scale ranging from 0 to 4. There were 12 items per subtest. Therefore, the maximum score on any given subtest was 48.

Sociological Measures

The Duke Social Support Index (DSSI; George et al, 1989) was used to measure both availability and satisfaction with social support. The DSSI includes 33 items comprising four subscales: subjective social support, social network, social interaction, and instrumental social support. A total subscale score is obtained through the sum of individual items and each scale score has been dichotomized into "impaired" and "non-impaired" based on respondent scores. The higher the score, the greater the social functioning.

Audiometric Measures

Memory. The California Verbal Learning Test (CVLT; Delis et al, 1987) is a standardized test of verbal learning and memory. The test is given by the oral presentation of a "shopping" list of 16 items over 5 immediate-recall trials. The words on the list are presented in the same order on all five trials and the subjects are asked to recall the items in any order. The lists include items from semantic categories (such as fruits, tools, etc.). The CVLT thus allows examiners to investigate whether subjects use effective cognitive strategies.

Attention. The Timed Sustained Attention Test (TSAT) is a laboratory measure of various attentional skills (Mahurin and Pirozzolo, 1986) and is standardized on a variety of clinical and normal populations. The test measures cognitive speed, flexibility, and concentration. Individual items include counting backwards, number subtractions, mental set shifting tasks, and recall of overlearned sequences (e.g., months of the year).

Manual Dexterity. The Purdue Pegboard test measures simple and complex manual dexterity. The subject is asked to insert pegs in a row of holes for a 30-sec time period, with both the dominant and nondominant hand. The purpose in the present study was to assess the extent to which visuomotor coordination affects successful use of amplification systems.

Standardized measures of finger oscillation and grip strength (using Lafayette commercial instrumentation) were also administered to rule out weakness and dyscoordination as factors in the successful manipulation of the small controls on contemporary hearing aids.

Central Auditory Processing Status. PTs were categorized into two subgroups on the basis of results on the DSI test (Fifer et al, 1983). In this test, two different sentences, selected from a closed set of 10 possible target sentences (Speaks and Jerger, 1965), are presented to the two ears simultaneously. The DSI test was presented in two conditions: free report (FR) and directed report (DR). In the FR task, the PT
scanned a list of the 10 sentences and reported the two numbers corresponding to the two sentences heard. In the DR task, the PT heard the two sentences but reported only one sentence. That is, prior to the presentation of a block of 10 sentences, PT was precued to report, during that block, only the sentence heard in the precued ear.

The rationale for this dual-mode approach is that it helps to differentiate between the two principal factors underlying performance on the dichotic task: (1) an auditory-structural factor deriving from the anatomy of the auditory pathways, the corpus callosum, and the cerebral hemispheres, which accords the right ear privileged access to the left hemisphere; and (2) a task-related factor deriving from the demands placed on cognitive processing, according to the instructional set under which the PT operates.

The FR mode places relatively greater stress on cognitive processing than the DR mode. The PT must attend to both ears, report one sentence while remembering the other, then report the second. In the DR mode, in contrast, the demands on cognitive processing are attenuated. The PT hears the same two sentences that were heard in the FR mode in both ears, but he/she may disregard what is heard in the nontarget ear, focus on what is heard in the target ear, and report just that one sentence. Thus, if the PT shows a dichotic deficit in the FR mode, but that deficit disappears or is greatly diminished in the DR mode, then it can be argued that the original dichotic deficit was wholly or partly cognitive in nature. If, on the other hand, there is no difference between the dichotic deficits measured in the two modes, then one can make a strong case for an additional auditory/structural deficit, since lessening of the cognitive demands of the task did not improve performance. Such an auditory/structural deficit has been linked to central auditory processing difficulties in children (Musiek et al., 1984) and may be presumed to underlie at least some aspects of central auditory problems in elderly persons.

The presentation level for DSI sentences was always at a sensation level of 20 dB relative to the PTA of the poorer ear. This same physical intensity was also the presentation level to the better ear. Thus, if the PTA was 30 dB HTL on the better ear and 40 dB HTL on the poorer ear, then the presentation level was 60 dB HTL on both ears. The purpose of this procedure was to ensure adequate audibility of the DSI sentences on the poorer ear while preserving equal physical intensities of the two target sentences as a feature of the test.

The DSI test results were scored as abnormal according to the criteria delineated in Fifer et al. (1983). In this way, results of both the FR and DR modes were scored. On the basis of these results, we categorized PTs into two groups, "DSI normal" and "DSI abnormal." If there were no DSI abnormalities in either mode, the PT was classified as DSI normal. The auditory deficit was attributed solely to peripheral (i.e., cochlear) deficit. If the DSI result was scored as abnormal in the FR mode but normal in the DR mode, then the PT was considered to have a purely cognitive dichotic deficit. It was assumed that the peripheral auditory deficit was accompanied by cognitive deficit, since there was a dichotic deficit in the FR mode but not in the DR mode. For purposes of the present paper, these subjects were also categorized as DSI normal since the dichotic deficit in the FR mode was eliminated by attenuating the cognitive demands of the listening task in the DR mode.

If the DSI scores were abnormal in both the FR and DR modes, then the subject was classified as DSI abnormal. It was assumed that the peripheral auditory deficit was accompanied by a central auditory processing deficit, since there were deficits in both the FR and DR modes. It should be noted that this is a more stringent definition of central deficit than simply an abnormally low score on the DSI in one test condition. Before a PT was classified as DSI abnormal, we required that there be an abnormality on at least one ear in both the DR and the FR modes of test administration. This took the form of a significantly reduced score on the same ear in both modes. There was a total of 33 PTs in the DSI-abnormal category. In 13 of these PTs, the deficit, in both the DR and FR modes, was on the right ear. In 20 PTs, the unilateral deficit was on the left ear.

Outcome Measure

The Hearing Handicap Inventory for the Elderly (HHIE) (Ventry and Weinstein, 1982) was administered to all PTs. A modification of the HHIE, the HHIE-SO, was administered to the PT's SO. The HHIE is a 25-item inventory that consists of two subscales, a 13-item subscale that explores emotional consequences and a 12-item subscale that examines both the social and situational effects of hearing impairment. In the case of PTs, questionnaires were administered in a face-to-face mode, although the PT actually entered ratings on the HHIE form. In the case of SOs, the HHIE form was filled out at home by
the SO. The scoring system results in a possible outcome between 0 and 100 percent, where 0 percent indicates no handicap and 100 percent indicates maximum handicap. Weinstein and Ventry (1983) have reported that a score of 17 percent or more denotes significant handicap.

Data Analysis

Effect of First-time Hearing Aid Use

In order to study the effect of DSI status on improvement with amplification, we elected to study a subgroup of 63 PTs who had not used hearing aids previously. This decision was based on the consideration that, in persons who have had previous experience with hearing aids, it is difficult to obtain a baseline measure of handicap in the no HA condition. Previous users may find it difficult to assess handicap in the unamplified condition because they have become used to functioning in the amplified state. In persons who have not previously used amplification, however, one is more likely to obtain an unbiased estimate of handicap without hearing aid use. The total group was divided into two subgroups according to results on the DSI test. There were 42 PTs in the DSI-normal group (29 men and 13 women) and 21 PTs in the DSI-abnormal group (13 men and 8 women).

Comparison of PT and SO

In order to compare the HHIE scores of PTs and their SOs, we selected from the total pool of 115 PTs a subgroup of 89 individuals. Since a history of prior hearing aid use was not relevant to this comparison, we added, to the 63 PTs described above, an additional 26 PTs who were previous hearing aid users, for a total of 89 PTs and their SOs. The additional 26 were chosen from the remainder of the total pool of 115 on the basis that average hearing sensitivity loss was matched in the DSI-normal and DSI-abnormal subgroups. There were 56 PTs (36 men and 20 women) in the DSI-normal category and 33 PTs (21 men and 12 women) in the DSI-abnormal category. Ages ranged from 60 to 85 years (mean = 72.1 years) in the DSI-normal category, and from 60 to 90 years (mean = 73.9 years) in the DSI-abnormal category. In the SO group there were 16 men and 73 women, ranging in age from 23 to 84 years. Sixty-two SOs were spouses of the PT, 13 were friends, 11 were sons/daughters or sons-in-law/daughters-in-law, 1 was a cousin, and 2 were neighbors. Seven SOs were hearing aid users. The aid had been worn for an average of 8.9 years. The average duration of acquaintance of the PT and his/her SO was 39.9 years, and ranged from 6 months to 76 years.

Effect of Practice on HHIE Scores

For this analysis, neither previous hearing aid use nor matching DSI groups for sensitivity loss seemed relevant. Accordingly, we analyzed the practice effect on HHIE in the entire pool of 115 PTs. For this analysis, there were 82 PTs with normal DSI results and 33 PTs with abnormal DSI results.

Statistical Analysis

To compare DSI groups on subject descriptor measures, we employed unpaired t tests. To compare DSI groups as a function of treatment condition, we employed a mixed-design analysis of variance (ANOVA) with one between-subjects factor (Group) and one within-subjects factor (treatment condition). Because of the presumed statistical dependence between the handicap estimated by PT and the handicap estimated by that PT's SO, we elected to treat the two estimates as paired, correlated data. Thus, when comparing the means of respondent groups on a single factor, or variable, we elected to employ the paired t test. Similarly, when two groups were compared across more than one factor or variable, as in the ANOVA, we elected to treat the respondent dimension as a within-subject, rather than a between-subjects, factor. Statistical significance was evaluated at an alpha level of 0.05.

RESULTS

Results are analyzed in three sections. In the first section, we analyze the HHIE scores of 63 first-time hearing aid users, grouped according to DSI status. In the second section, we compare the HHIE scores of 89 PTs and their SOs, again grouped according to DSI status. In this larger group, some were previous hearing aid users. In the third section, we consider the effect of practice on the HHIE score in the total pool of 115 PTs.

Effect of First-time Hearing Aid Use (N = 63)

Pure-tone Audiometric Sensitivity Loss

Figure 1 shows average audiograms for the right and left ears of subjects in the two DSI
groups. The 63 PTs analyzed in this section had not used hearing aids prior to this experience. They were selected from the larger pool of 115 study patients with the specific aim of matching mean audiograms of the DSI-normal and DSI-abnormal groups. This matching was carried out in order to ensure that group differences on HHE could not be attributed to interaural asymmetry in peripheral hearing sensitivity. In both groups, the audiometric contours of both ears were consistent with the sensorineural hearing loss typically associated with presbyacusis.

Subject Descriptors

We ask first whether the two DSI groups can be distinguished on the basis of audiologic, neuropsychological, or sociological measures.

Audiologic Measures. Table 2 shows the distributions of conventional speech audiometric scores. The DSI-abnormal group tended to score less well than the DSI-normal group, but intergroup differences were statistically significant only for the PB max score on the left ear. Interestingly, both the PB and SSI measures reflect poorer average performance on the left ear than on the right ear. This interaural difference was observed in both groups but was substantially larger in the DSI-abnormal group. Again, however, these interaural differences were not statistically significant by paired t test in either group. It should be re-emphasized that these interaural differences in average speech audiometric scores were observed even though average pure-tone audiometric sensitivity was matched in the two ears.

Neuropsychological Measures. The next section of Table 2 summarizes neuropsychological measures for the two groups. There were no significant differences between subgroups on any of the five personality measures (NEO-FFI), on the memory task (CVLT), or on the attention task (TSAT). Nor were there significant differences between the two subgroups on any of the three measures of manual dexterity. Results of these measures of cognitive, affective, and motor function are remarkable for their similarity between the two subgroups. No significant differences in any measure were noted.

Sociological Measures. Key findings on the four sociological measures of the DSSI are also summarized in Table 2. The higher the score on each of the subscales, the greater the social functioning of the subjects. There were no intergroup differences on any of the sociological measures: social network, social interaction, instrumental support, or subjective social support. In general, PTs in both groups were non-impaired with respect to social network and social interaction, and all reported receiving adequate social support. Specifically, 2 of the 63 PTs (3%) were impaired with respect to social network (relatives or other acquaintances who live in close proximity or with whom one speaks on a day-to-day basis). In fact, this study sample had a higher mean score than the population of older people studied through the NIA EPES.
Table 2  Means and Standard Deviations on Subject Descriptor Measures for PTs Divided Into Two Categories on the Basis of DSI Results

<table>
<thead>
<tr>
<th>Subject Descriptor</th>
<th>DSI Normal ( (n = 42) )</th>
<th>DSI Abnormal ( (n = 21) )</th>
<th>Difference</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Age</td>
<td>72.4 ( (5.6) )</td>
<td>70.3 ( (7.1) )</td>
<td>2.1</td>
<td></td>
<td></td>
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<tr>
<td><strong>Audiologic Measures</strong></td>
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<tr>
<td>PTA1 (dB HL)</td>
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<tr>
<td>Right ear</td>
<td>32.4 ( (11.5) )</td>
<td>33.1 ( (16.2) )</td>
<td>-0.7</td>
<td>0.22</td>
<td>.825</td>
</tr>
<tr>
<td>Left ear</td>
<td>35.1 ( (10.2) )</td>
<td>37.7 ( (13.7) )</td>
<td>-2.6</td>
<td>0.86</td>
<td>.392</td>
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<tr>
<td>PTA2 (dB HL)</td>
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<tr>
<td>Right ear</td>
<td>44.8 ( (10.3) )</td>
<td>46.4 ( (13.1) )</td>
<td>-1.6</td>
<td>0.50</td>
<td>.616</td>
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<tr>
<td>Left ear</td>
<td>47.3 ( (9.3) )</td>
<td>50.7 ( (13.8) )</td>
<td>-3.4</td>
<td>1.14</td>
<td>.258</td>
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<tr>
<td>PB (% correct)</td>
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<tr>
<td>Right ear</td>
<td>68.8 ( (18.5) )</td>
<td>59.8 ( (29.4) )</td>
<td>9.0</td>
<td>1.48</td>
<td>.114</td>
</tr>
<tr>
<td>Left ear</td>
<td>66.1 ( (18.4) )</td>
<td>54.1 ( (25.4) )</td>
<td>12.0</td>
<td>2.13</td>
<td>.037</td>
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<tr>
<td>SSI (% correct)</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Right ear</td>
<td>75.2 ( (24.5) )</td>
<td>72.4 ( (28.6) )</td>
<td>2.8</td>
<td>0.41</td>
<td>.686</td>
</tr>
<tr>
<td>Left ear</td>
<td>73.2 ( (25.8) )</td>
<td>61.4 ( (32.1) )</td>
<td>11.8</td>
<td>1.56</td>
<td>.123</td>
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<td><strong>Neuropsychological Measures</strong></td>
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<tr>
<td>NEO-FFI (personality)*</td>
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<tr>
<td>Neuroticism</td>
<td>15.3 ( (5.6) )</td>
<td>17.8 ( (5.0) )</td>
<td>-2.5</td>
<td>1.73</td>
<td>.088</td>
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<tr>
<td>Extraversion</td>
<td>28.5 ( (5.8) )</td>
<td>27.9 ( (5.9) )</td>
<td>0.6</td>
<td>0.41</td>
<td>.682</td>
</tr>
<tr>
<td>Obsessiveness</td>
<td>26.0 ( (5.5) )</td>
<td>26.6 ( (5.2) )</td>
<td>-0.6</td>
<td>0.41</td>
<td>.683</td>
</tr>
<tr>
<td>Agreeableness</td>
<td>31.5 ( (5.9) )</td>
<td>31.2 ( (5.3) )</td>
<td>0.3</td>
<td>0.19</td>
<td>.852</td>
</tr>
<tr>
<td>Compulsiveness</td>
<td>31.9 ( (5.4) )</td>
<td>33.3 ( (5.0) )</td>
<td>-1.4</td>
<td>1.03</td>
<td>.308</td>
</tr>
<tr>
<td>CVLT†</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Raw</td>
<td>40.3 ( (7.0) )</td>
<td>39.7 ( (8.5) )</td>
<td>0.6</td>
<td>0.30</td>
<td>.769</td>
</tr>
<tr>
<td>Standard</td>
<td>41.9 ( (8.4) )</td>
<td>40.8 ( (9.1) )</td>
<td>1.1</td>
<td>0.52</td>
<td>.602</td>
</tr>
<tr>
<td>TSAT†</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Time (sec)</td>
<td>83.7 ( (21.2) )</td>
<td>80.4 ( (17.8) )</td>
<td>3.3</td>
<td>0.61</td>
<td>.544</td>
</tr>
<tr>
<td><strong>Manual Dexterity</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pegboard (sec)§</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right hand</td>
<td>95.4 ( (22.3) )</td>
<td>95.4 ( (21.9) )</td>
<td>0.0</td>
<td>0.01</td>
<td>.990</td>
</tr>
<tr>
<td>Left hand</td>
<td>110.5 ( (32.3) )</td>
<td>101.4 ( (21.1) )</td>
<td>9.1</td>
<td>1.16</td>
<td>.249</td>
</tr>
<tr>
<td>Fingertap (taps per 10 sec)#</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right hand</td>
<td>42.8 ( (11.7) )</td>
<td>44.8 ( (12.6) )</td>
<td>-2.0</td>
<td>0.61</td>
<td>.543</td>
</tr>
<tr>
<td>Left hand</td>
<td>39.6 ( (10.3) )</td>
<td>42.9 ( (11.1) )</td>
<td>-3.3</td>
<td>1.14</td>
<td>.259</td>
</tr>
<tr>
<td>Handgrip (kg)**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right hand</td>
<td>29.6 ( (9.7) )</td>
<td>32.0 ( (13.8) )</td>
<td>-2.2</td>
<td>0.72</td>
<td>.477</td>
</tr>
<tr>
<td>Left hand</td>
<td>27.8 ( (9.9) )</td>
<td>29.7 ( (13.4) )</td>
<td>-1.9</td>
<td>0.63</td>
<td>.528</td>
</tr>
<tr>
<td><strong>Sociological Measures</strong></td>
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<td></td>
</tr>
<tr>
<td>Duke Social Support Index†</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social network</td>
<td>5.9 ( (2.6) )</td>
<td>5.7 ( (1.8) )</td>
<td>0.2</td>
<td>0.30</td>
<td>.766</td>
</tr>
<tr>
<td>Social interaction</td>
<td>7.3 ( (2.4) )</td>
<td>7.1 ( (2.5) )</td>
<td>0.2</td>
<td>0.26</td>
<td>.798</td>
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<tr>
<td>Instrumental support</td>
<td>10.3 ( (3.4) )</td>
<td>9.9 ( (3.0) )</td>
<td>0.4</td>
<td>0.50</td>
<td>.621</td>
</tr>
<tr>
<td>Subjective social support</td>
<td>26.3 ( (2.1) )</td>
<td>26.0 ( (2.4) )</td>
<td>0.3</td>
<td>0.44</td>
<td>.658</td>
</tr>
</tbody>
</table>

Also shown are differences between groups on the various measures and t and p values from unpaired t tests.

*5-point scale — higher number means more of the trait; †memory — higher number means better memory; ‡attention — lower number means better attention; §lower number means better dexterity; #higher number means better dexterity; **higher number means better dexterity; †’DSSI — higher number means more social support.

Program involving thousands of persons over 60 years (Cornoni-Huntley et al, 1986, 1990). With respect to social interaction, only two (3%) of the PTs were impaired with respect to opportunities to interact by phone or in person with others in contrast to national norms, which were 16 percent of the population over 60 years. The findings for subjective social support and instrumental support are similar. All but two (3%) of the PTs (not the same two noted in the previous sentence) reported adequate assistance with daily activities and only six (9.5%) were impaired
with respect to their assessment of support from family and friends. PTs reported greater affective and instrumental support from SOs than the populations of older people studied through the NIA EPES Program, where 13.5 percent of individuals were impaired with respect to subjective social support in contrast to 9.5 percent in this study. In spite of hearing loss, the PTs had not experienced actual or perceived lack of support from family and friends.

**HHIE Scores**

In this section, we compare self-assessed handicap ratings of PTs at baseline and after hearing aid use in the two DSI groups. Figure 2 shows average HHIE scores and their standard errors for the two DSI groups, as reported by the PTs. In the DSI-normal group, the HHIE score declined from 29.0 percent in the baseline condition to 20.7 percent after 6 weeks of hearing aid use. In the DSI-abnormal condition, however, the average HHIE score changed by only 0.9 percent — from 31.2 percent in the baseline condition to 30.3 percent after hearing aid use. A mixed-design ANOVA, with one between-subjects factor (DSI category) and one within-subjects factor (baseline vs hearing aid treatment), showed a significant interaction between DSI group and treatment condition (F = 4.21, p = .044) and a significant difference between baseline and treatment conditions (F = 12.0, p < .001). The significant interaction may be interpreted to mean that the effect of the hearing aid treatment was different for the two DSI groups. The significant treatment effect clearly derives from the improvement in the DSI-normal group only. It is the case that the DSI-abnormal group rated themselves as slightly more handicapped than the DSI-normal group, but the difference (2.2%) was not significant by unpaired t test.

**HHIE Scores of PTs vs SOs (N = 89)**

How do handicap ratings by PT compare with the ratings made by PTs’ SOs. For this analysis, we selected, from the original pool of 115 study patients, a subset of 56 individuals with normal DSI scores and 33 individuals with abnormal DSI scores. Again, average audiometric thresholds were matched in the two DSI groups. For the right ear, the PTA was 39.9 dB HTL and the PTA2 was 50.4 dB HTL. For the left ear, the PTA was 42.1 dB HTL and the PTA2 was 52.3 dB HTL. Twenty-six of the 89 PTs in this analysis were previous hearing aid users. Like the PTS who had not previously used aids, the HA treatment effect was quantified by comparing the HHIE score after HA use with the HHIE score based on perceived handicap without hearing aid use. Figure 3 compares average HHIE scores of PT and SO in the baseline

![Figure 2](image1.png)

**Figure 2** Mean HHIE scores, and their standard errors, at baseline and after 6 weeks of first-time hearing aid use. Comparison is between DSI-normal and DSI-abnormal groups. In the DSI-normal group, there was significant reduction in the average handicap score, after 6 weeks of amplification, but in the DSI-abnormal group, there was no significant change in perceived handicap.

![Figure 3](image2.png)

**Figure 3** Mean HHIE scores, and their standard errors, in the baseline condition, for 89 PTs, grouped according to DSI category. Comparison is between HHIE scores of PTs and SOs.
Figure 4  Mean HHIE scores, and their standard errors, of the 89 PTs of Figure 3, after 6 weeks of hearing aid use, grouped according to DSI category. Comparison is between HHIE scores of PTs and SOs.

Figure 5  Mean improvement in HHIE scores after 6 weeks of hearing aid use for DSI-normal and DSI-abnormal subgroups. Comparison is between improvement scores of PTs and SOs.

condition, Figure 4 compares the two scores after the 6-week hearing-aid treatment condition, and Figure 5 replots the same data as improvement following amplification (baseline score minus score after amplification). A mixed-design ANOVA, with one between-subjects factor (DSI category) and two within-subjects factors (amplification condition and respondent) yielded a significant main effect for DSI category \( F = 4.59, p = .035 \), a significant main effect for amplification condition \( F = 17.03, p < .0001 \), a significant main effect for respondent \( F = 5.97, p = .017 \), and a significant interaction between DSI category and amplification condition \( F = 4.04, p = .048 \). These results may be interpreted to mean that, on average, the SO rates the handicap greater than the PT, that handicap is rated greater in the DSI-abnormal group, that there is significant reduction of handicap by amplification, and that this reduction is greater in the DSI-normal than in the DSI-abnormal group.

Effect of Order of HA Condition

Since the HA condition was only one of four different experimental conditions to which the PT was exposed during the 6-month study period, and since the order of these conditions was random, it might be the case that grouping by DSI status introduced a bias in the position of the HA condition favoring one of the two DSI subgroups.

To examine this possibility, we calculated the percentage of time that the HA condition occurred first, second, third, and fourth in the sequence of experimental conditions. In the present DSI-normal PTs, the HA condition was first in 22 percent, second in 23 percent, third in 34 percent, and fourth in 21 percent. In the DSI-abnormal PTs, the HA condition was first in 33 percent, second in 24 percent, third in 24 percent, and fourth in 18 percent. Thus, there was no evident substantial bias favoring one subgroup in terms of position of the hearing aid treatment condition over the entire test protocol.

Effect of Practice on HHIE Scores

Since the same HHIE scale was administered two or more times to the same PT and SO over the course of the total observation period, it is relevant to ask to what extent the improvement in HHIE scores noted in the present results was influenced by a possible practice effect. In a previous study of the test–retest reliability of the HHIE, Weinstein et al (1986) reported, for face-to-face administration, a 1.0 percent decrease in the mean HHIE score from test to retest in a group of 27 elderly veterans. The interval between test and retest was approximately 6 weeks. Later, Newman and Weinstein (1989) compared face-to-face administration on first test with paper-and-pencil administration on retest after 6 weeks in 19 elderly veterans. The mean improvement was 1.9 percent. These
data suggest that the mean practice effect should not exceed 2 percent.

Two lines of evidence suggest that such a practice effect did not invalidate the present results. First, the key finding of the present study, that elderly persons with central deficit report less reduction in handicap from hearing aid use than elderly persons without such deficit, was revealed by a significant interaction between improvement in handicap and DSI group, a relative measure of group difference rather than an absolute measure of treatment effect.

Second, we can derive, from the present data, a rough estimate of the actual practice effect in the present study by comparing HHIE scores in the baseline condition with HHIE scores in the experimental condition in which handicap was re-rated after a 6-week period in which no amplification was used. After the baseline measures had been taken, the PTs underwent four experimental conditions: one was the hearing aid condition (HA) with which the present paper is concerned. Another was a 6-week period in which no amplification (no HA) was used. Both the HA and no HA conditions occurred randomly across the four conditions. The difference between the mean HHIE score at baseline and in this no HA condition may slightly overestimate the practice effect since it may be influenced by the intervening true amplification conditions. It serves, therefore, as a "worst-case" estimate of the possible practice effect. We first analyzed the two DSI categories separately. In the DSI-normal category, the average practice effect for PTs was 2.4 percent. In the DSI-abnormal category, the analogous value was 1.7 percent. In view of the similarity of these two values, we collapsed across DSI category to compute an overall practice effect for the entire group. We calculated, for the PTs, the mean HHIE at baseline (36.2%) and the mean HHIE in the no HA condition (34.1%), an improvement of 2.1 percent. For the SOs, the analogous data were 40.4 percent at baseline and 38.6 percent at no HA, for a difference of 1.8 percent. For these same 115 PTs, the difference between baseline and the HA condition was 5.6 percent for PT and 6.2 percent for SO. We then carried out a repeated-measures ANOVA for the 115 subjects across the three HHIE conditions (baseline, no HA, and HA). For the PTs, the main effect was significant ($F = 11.6, p < .0001$). Post hoc comparisons of condition pairs (Scheffe F-test) showed that the difference between baseline and HA was significant ($F = 11.45, p < .05$) and the difference between no HA and HA was significant ($F = 4.24, p < .05$), but the difference between baseline and no HA was not. A similar result was observed after analysis of the SO data. The differences between baseline and HA, and between no HA and HA, were significant, but the difference between baseline and no HA was not. These results confirm a significant improvement in HHIE score after amplification, over and above the worst-case estimate of the test–retest practice effect.

DISCUSSION

Effect of Amplification

The present results reaffirm that intervention with a hearing aid is, indeed, efficacious in attenuating the perceived hearing handicap of elderly persons with hearing impairment who have not previously used amplification. That fact is reflected in the average change in handicap scores of both PTs and their SOs.

Effect of Central Auditory Deficit

Since aging is accompanied by decline in cognitive as well as auditory function, a persistent question has been the extent to which the auditory problems of the elderly can be explained by concomitant decline in such cognitive functions as personality, memory, and attention (CHABA Working Group, 1988; Jerger et al, 1989; Willott, 1991). It is of interest to note, therefore, that in the present subjects (Table 2), there were no significant differences between the two DSI subgroups on measures of personality (NEO-FFI), memory (CVLT), or attention (TSAT). Of further interest is the fact that there were no significant differences in manual dexterity between the two subgroups. Thus, the smaller reduction in HHIE scores in the DSI-abnormal group cannot be explained either by differences in the cognitive dimensions of personality, memory, or attention or by differences in the fine motor control necessary for the successful manipulation of the subminiature controls of modern hearing aids.

It is clear from the present results that central auditory deficit in elderly persons attenuates the improvement in quality of life afforded by amplification. Elderly persons with central deficits, as measured by a test of dichotic listening, showed significantly less improvement in self-reported handicap than elderly persons without such deficit. If audibility were the only problem facing elderly persons with sensorineural hearing loss (cf. Humes and Roberts, 1990; Humes and Christopherson, 1991), then there should have been no difference between our
two DSI groups in the extent to which the use of a hearing aid attenuated the perceived hearing handicap, since average audiometric levels were the same in the two groups. The present results are more consistent with the concept that the presence of central processing disorder prevents the elderly individual from realizing the full potential of amplification.

Self-report by Study Patient vs Significant Other

It is perhaps not surprising that the SO consistently judged the handicap to be somewhat greater than the PT himself/herself. In many ways, the SO, especially the spouse, bears a greater burden from the miscommunications and other problems arising from the PT's hearing impairment. It is interesting, therefore, that, in PTs with central auditory deficit, the SO reported a reduction in handicap as a result of hearing aid use even when the PT did not. Apparently, the use of the aid by the PT with central auditory deficit does reduce the stress on the SO in spite of the fact that the PT does not judge that the use of the aid lessens the handicap materially.

The direction of the present difference (SO judges greater handicap than PT) agrees with the direction observed in our previous paper (Chmiel and Jerger, 1993), but disagrees with the direction observed by Newman and Weinstein (1986). In the latter study, the handicap rated by the PT was greater than the handicap rated by the SO. However, all of the elderly subjects studied by Newman and Weinstein were male veterans who may have had some incentive to exaggerate the degree of loss. Presumably, the judgments of their SOs would be less influenced by such incentive.

Clinical Relevance

It is certainly the case that the HA treatment effects observed in the present study were small. In the DSI-normal category, the average treatment effect on the HHIE score was less than 10 percent. Nevertheless, the significant group differences in HHIE scores observed between the DSI-normal and DSI-abnormal groups may help to explain why some elderly persons seem reluctant to actually use hearing aids when our conventional tests suggest an optimistic prognosis. The present results show that, even though two elderly persons may have the same degree of peripheral hearing sensitivity loss, if one has a central processing deficit, that person will, on the average, perceive significantly less benefit from the use of the aid than the person without such deficit.

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REFERENCES


