0196/0202/87/0805-0270$02.00/0
EAR AND HEARING
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Vol. 8, No. 5
Printed in U.S.A.

HEARING AIDS AND AURAL REHABILITATION

Consonant Recognition and Confusion Patterns Among Elderly Hearing-Impaired Subjects*

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ABSTRACT

This study investigated whether unique consonant recognition and confusion patterns are associated with hearing loss among elderly listeners. Subjects were all >65 years, and had normal hearing, or gradually or sharply sloping sensorineural hearing losses. Recognition of 19 consonants, paired with each of three vowels in a CV format, was assessed at two speech levels in a background of babble (+6 dB signal-to-babble ratio). Analyses of percent correct scores for overall nonsense syllable performance and for consonants according to place, manner, and voicing categories generally revealed better performance by the normal-hearing subjects than by the hearing-impaired subjects. However, individual differences scaling analysis of consonant confusions failed to retrieve speech perception patterns that were unique to listener group. These results tentatively suggest that the presence and configuration of hearing loss among elderly listeners may affect the level of performance but not the specific pattern of performance.

Speech recognition performance by elderly listeners has received increasing attention in recent years because these listeners often exhibit poorer performance than younger listeners, especially in difficult listening conditions (1). Notably, performance deficits of elderly listeners are observed even when pure-tone thresholds are matched between young and elderly subjects. For example, Findlay and Denenberg (2) reported significantly poorer word recognition scores in noise by elderly hearing-impaired listeners than by younger hearing-impaired listeners. Similarly, Dubno et al (3) showed that elderly subjects with either normal hearing or mild hearing loss required more advantageous signal-to-babble ratios (S/Bs) to achieve criterion performance than younger listeners with matched audiograms. Thus, many elderly listeners with and without hearing loss exhibit more extensive word recognition problems in noise than younger listeners. However, the nature of the perceptual problem underlying the word recognition deficit is not well understood. More detailed analyses of speech perception performance than overall word recognition scores are needed to resolve the important attributes of the speech recognition deficits of elderly listeners.

One approach to specifying the speech recognition deficits of elderly listeners has been applied previously in studies with younger hearing-impaired listeners. In these studies, perceptual judgments of nonsense syllable stimuli by hearing-impaired listeners were examined. In addition to reporting overall percent correct scores, researchers have used multivariate analysis techniques to detail hearing-impaired listeners' patterns of consonant recognition, consonant confusions, and consonant similarity judgments. Most investigators have attempted to correlate performance patterns to specific hearing loss characteristics. For example, a systematic relationship between audiometric configuration and consonant confusion patterns was reported by Dubno et al (4) for nonsense syllables presented at a +20 dB signal-to-noise ratio (S/N). A similar finding was reported by Owens et al (5) for words presented in quiet. Analyses of perceptual dimensions underlying consonant similarity judgments or confusions have also shown that different audiometric configurations are associated with distinct patterns of important perceptual features. For example, Walden and Montgomery (6) examined consonant similarity judgments of hearing-impaired listeners in quiet, and used individual differences scaling (INDSCAL) to extract the perceptual dimensions underlying performance patterns. In addition, the weights associated with each dimension for each subject group were derived, which reflect the "importance" of each dimension to each subject group's performance. Walden and Montgomery found that performance of listeners with sharply sloping high-frequency losses was associated with a sonorance feature, whereas performance of listeners with relatively flat losses was associated with a sibilance feature; performance of normally hearing listeners was associated with these two features and a place feature. Configuration-specific patterns of important perceptual features derived from consonant confusion data obtained in quiet were

* This investigation was supported by grants from the National Institute on Aging and from the General Research Board of the University of Maryland. The computer time for this project was supported in part through the facilities of the Computer Science Center of the University of Maryland.

also reported by Reed (7) and Bilger and Wang (8). Thus, previous detailed examinations of hearing-impaired listeners' speech perception performances suggest that the combined effects of sensitivity loss and speech recognition deficit create a performance pattern that is configuration specific, particularly in quiet or highly favorable S/N listening conditions.

One characteristic of the foregoing studies is that the subjects in the hearing-impaired groups were either heterogeneous with respect to age or were all relatively young adults (<50 years). Because many elderly hearing-impaired subjects frequently perform more poorly than young hearing-impaired subjects on word recognition tasks, it is unclear whether the specific performance trends observed for younger hearing-impaired subjects on nonsense syllable perception tasks characterize those of elderly hearing-impaired subjects as well. Elderly hearing-impaired subjects potentially represent an ideal group for specifying consonant perception patterns, primarily because their performance on word recognition tasks frequently suggests the presence of a significant speech perception problem. Indeed, Gelfand et al (9) observed significant deficits in consonant recognition performance by elderly normally hearing subjects compared to younger subjects. These deficits were more pronounced in noise conditions (10). However, consonant recognition performance by elderly hearing-impaired subjects has not as yet been described specifically.

The present investigation examined and compared the patterns of nonsense syllable recognition performance exhibited by normally hearing and hearing-impaired elderly subjects. The aim was to determine whether specific performance patterns were associated with hearing loss among elderly subjects. In addition, performance trends exhibited by these elderly listeners were compared to those reported previously for younger hearing-impaired listeners to determine whether comparable trends in performance characterize the two different age groups.

METHOD

Subjects

Subject selection was guided by an effort to form groups whose audiometric configurations were representative of those of elderly listeners, but were also comparable to configurations used in previous studies. Thirty subjects, ranging from 65 to 75 years of age, were paid to participate in the experiment. They were assigned to one of three groups, with 10 subjects each, on the basis of hearing sensitivity. Subjects in group I (4 males, 6 females, mean age = 67.7 yr) had pure-tone threshold sensitivity within normal limits, defined as thresholds ≤20 dB HL (11) from 250 through 4000 Hz, and a threshold ≤25 dB HL at 8000 Hz. Subjects assigned to group II (6 males, 4 females, mean age = 69.3 yr) had sensorineural hearing losses with gradually-sloping audiometric configurations: pure-tone thresholds decreased by 5 to 15 dB/octave between 500 and 4000 Hz. Subjects in group III (4 males, 6 females, mean age = 68.4 yr) had sensorineural hearing losses with sharply-sloping audiometric configurations, as evidenced by a difference in pure-tone thresholds between 500 through 4000 Hz >45 dB or a difference in pure-tone thresholds between adjacent octave frequencies exceeding 30 dB. Pure-tone averages of all hearing-impaired subjects were <40 dB HL, suggesting that the hearing losses were generally mild-to-moderate in degree. Table 1 presents the mean audiograms of subjects in the three groups. Word recognition scores in quiet (NU 6 test) ranged from 96 to 100% for the normally hearing subjects, and from 78 to 92% for the hearing-impaired subjects. All subjects had normal tympanograms, and their acoustic reflex thresholds between 500 and 2000 Hz were elicited at levels below the 90th percentile upper limit established previously from subjects with cochlear lesions and different degrees of hearing loss (12). The primary etiology of the hearing loss for subjects in the two hearing-impaired groups was presbyacusis.

Stimuli and Noise

The stimulus set consisted of 19 consonants (b, d, g, p, t, k, m, n, s, z, ʃ, f, v, θ, ð, w, j, r, l) paired with each of three vowels (a, i, u) in a consonant-vowel (CV) format. These stimuli were recorded by a trained male speaker with a General American dialect in an anechoic chamber. Subsequently, the stimuli were low-pass filtered (7 kHz cutoff), analog-to-digital (AD) converted onto an LSI 11/23 microcomputer system (16 kHz rate), and scaled in level to equate vowel peak amplitude across stimuli. This procedure had the effect of peaking each CV at the same level on a VU-meter. Details of the procedure are presented elsewhere (13).

A recording of 12-talker babble was used as the background noise during the experiment. The babble was recorded such that maximum fluctuations in level did not exceed ±4 dB of the baseline. The babble's spectrum is comparable to the long-term average speech spectrum (14).

Procedures

Six listening conditions were used in which the consonant stimuli were presented in three vowel contexts (/a, i, u/) at each of two speech levels (75 and 90 dB SPL). Each condition was presented to each subject, and consisted of 10 randomized presentations of each CV. The stimuli were presented at a +6 dB S/B during each condition. The order of conditions was randomized across subjects.

Stimulus presentation and data collection were controlled by microcomputer. The stimuli were DA converted (16 kHz rate), low-pass filtered (7 kHz cutoff), amplified, and mixed with the taped babble. The signal and noise were then attenuated, amplified, and presented monaurally to a TDH-49 earphone. The test ear was the right ear for normally hearing subjects and the ear with better threshold sensitivity for hearing-impaired subjects.

The subject's task was to push one of 19 buttons on a response box, corresponding to the signal perceived. The stimulus labels were displayed alphabetically on the response box in orthographic form. After the subject responded, a 1-sec delay preceded the onset of the next stimulus presentation.

A practice session was conducted prior to the experimental sessions to familiarize the subjects with the stimuli and response

Table 1. Average pure-tone thresholds of the three listener groups

	Normally Hearing		Gradual Slope		Sharp Slope	
Frequency (in Hz)	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
250	10.0	6.6	16.0	9.4	11.5	5.8
500	9.0	8.1	20.0	9.5	7.5	5.9
1000	10.5	7.2	27.0	7.1	10.5	8.3
2000	11.5	5.8	37.0	8.2	30.5	19.2
4000	15.5	6.8	48.0	13.6	59.0	9.4
8000	19.5	6.2	60.0	12.2	69.5	11.6

paradigm. During the practice, two randomizations of all CVs in one vowel context were presented without the background babble added. The identification responses were checked for accuracy. If an error occurred for a consonant phoneme, then the subject was asked to read aloud the orthographic representation of that test item. Testing continued when the subject was able to identify correctly each item on the response box. However, subjects were never given feedback regarding the accuracy of their responses. Thus, the practice was sufficient to familiarize subjects with the response buttons, but was not necessarily sufficient to train subjects to asymptotic recognition performance.

A 1 kHz tone whose sound pressure level was equal to the peak level of each stimulus was used for calibration. The nonsense syllable stimuli were calibrated to the level of this tone which was adjusted to produce either 75 or 90 dB SPL at the earphone output, as measured in an NBS-9A 6 cm^3 coupler. The overall level of the babble was adjusted to produce either a 69 dB SPL or 84 dB SPL coupler response output, to create a +6 dB S/B for the two speech levels, respectively.

Testing was conducted in a double-walled sound-isolated chamber. The entire testing procedure was completed within 2.5 hr.

RESULTS

Nonsense Syllable Recognition

The average percent correct recognition scores from each subject group in the six listening conditions are shown in Figure 1. Individual subject scores were arc-sine transformed to remove the relationship between treatment means and variances which exist in proportional data (15). These transformed scores were subjected to analysis of variance (ANOVA), with one between-subjects factor (hearing sensitivity) and two within-subjects factors (vowel and level). The results revealed significant main effects of group [$F(2,27) = 8.17$, $p < 0.01$] and vowel [$F(2,54) = 52.28$, $p < 0.01$], and significant interactions between group and vowel [$F(4,54) = 4.45$, $p < 0.01$] and between group and stimulus level [$F(2,27) = 6.85$, $p < 0.01$].

Simple main effects analyses revealed that group was a significant effect for stimuli paired with /a/ and /i/ ($p < 0.01$), but not with /u/, at both presentation levels. Multiple comparison tests (Scheffe's) further showed that the normally hearing subjects exhibited significantly higher scores than the two hearing-impaired subject groups in

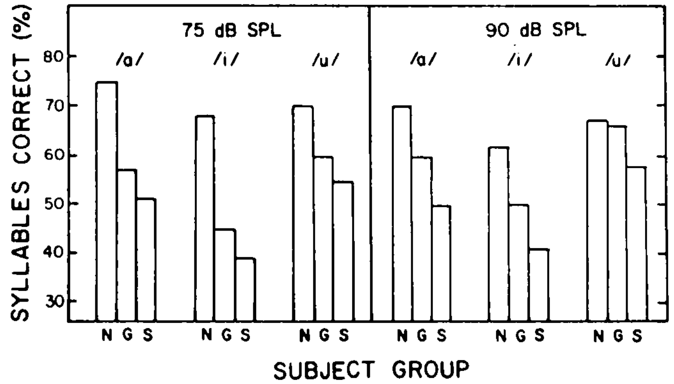

Figure 1. Mean nonsense syllable recognition scores from subjects with normal hearing, gradually sloping losses, and sharply sloping losses, in three vowel contexts and two speech levels.

the /a/ and /i/ contexts at 75 dB SPL. However, at 90 dB SPL, recognition scores of both the normally hearing subjects and the subjects with gradually sloping losses exceeded the scores of the subjects with sharply sloping losses.

Vowel effects were significant for the two hearing-impaired groups, and similar vowel effects were observed for each group. Subjects with both gradually sloping losses and sharply sloping losses recognized consonants paired with /u/ with greater accuracy than consonants paired with /i/.

Phoneme Class Recognition

An analysis of correct recognition of phonemes according to feature class was undertaken to detail possible differences in correct recognition performance patterns of the different subject groups. Separate analyses of accurate recognition of consonant place, manner, and voicing were conducted. For the place analysis, accurate recognition of the front, mid, and back-place consonants was calculated from each subject's data in each condition. For the manner analysis, percent correct recognition for five manner categories (plosives, nasals, fricatives, sibilants, glides/liquids) was derived from each subject's data in each condition. Accurate recognition of the voiced-voiceless cognates was calculated from each subject's data in the voicing analysis. An ANOVA was performed on arc-sine transformations of the individual percent correct scores for each set of data. Separate ANOVAs were conducted for each vowel context and speech level, because these two factors interacted with listener group in the main analysis.

Table 2 presents the significant main effects and interactions observed in the analyses. Simple main effects analyses and multiple comparison testing were conducted on all significant effects. A summary of findings specific to group differences will be discussed.

Performance differences between subject groups varied with presentation level. In analyses where hearing was a significant effect, normally hearing subjects always outperformed subjects with sharply sloping losses. In addition, normally hearing subjects always performed better than subjects with gradually sloping losses at 75 dB SPL, and occasionally performed better than these subjects at 90 dB SPL (e.g., voicing analysis, /a/ and /i/ contexts; manner analysis, /u/ context, for fricatives and glides/liquids). The two hearing-impaired groups generally did not exhibit performance differences among them, except for recognition of voiced-voiceless consonants at 90 dB SPL (/i/ context). In this case, subjects with gradually sloping losses demonstrated higher recognition performance than subjects with sharply sloping losses.

Specific patterns of consonant recognition varied with listener group in only a few place and manner analyses, but not in any of the voicing analyses. Generally, normally hearing listeners exhibited different patterns of consonant recognition than did the two hearing-impaired groups, but the two hearing-impaired groups showed virtually no performance differences between them. For example, normally hearing subjects recognized front-place consonants more accurately than either mid- or back-place consonants (/a/ context, 75 dB SPL). Conversely, both hearing-im-

Table 2. ANOVA results of significance, for consonant recognition according to place, manner, and voicing categories

Condition	Effect	F value (df) ($p < 0.01$)	
Place analysis			
/a/, 75 dB SPL	hearing	7.60	(2, 27)
	place	42.73	(2, 54)
	hearing × place	13.38	(4, 54)
/i/, 75 dB SPL	hearing	7.52	(2, 27)
	place	52.72	(2, 54)
/u/, 75 dB SPL	hearing	9.39	(2, 27)
	place	20.91	(2, 54)
/a/, 90 dB SPL	hearing	3.60	(2, 27)*
	place	22.06	(2, 54)
/i/, 90 dB SPL	hearing	7.07	(2, 27)
	place	14.71	(2, 54)
/u/, 90 dB SPL	place	17.53	(2, 54)
Manner analysis			
/a/, 75 dB SPL	hearing	15.21	(2, 27)
	manner	70.75	(4, 108)
/i/, 75 dB SPL	hearing	6.68	(2, 27)
	manner	75.01	(4, 108)
/u/, 75 dB SPL	manner	31.19	(4, 108)
	hearing × manner	3.54	(8, 108)
/a/, 90 dB SPL	hearing	8.90	(2, 27)
	manner	64.28	(4, 108)
/i/, 90 dB SPL	hearing	5.46	(2, 27)*
	manner	60.91	(4, 108)
/u/, 90 dB SPL	manner	52.98	(4, 108)
	hearing × manner	3.34	(8, 108)
Voicing analysis			
/a/, 75 dB SPL	hearing	9.85	(2, 27)
	voicing	66.04	(1, 27)
/i/, 75 dB SPL	hearing	8.92	(2, 27)
	voicing	11.98	(1, 27)
/u/, 75 dB SPL	voicing	35.91	(1, 27)
/a/, 90 dB SPL	hearing	5.51	(2, 27)
	voicing	25.47	(1, 27)
/i/, 90 dB SPL	hearing	8.31	(2, 27)
	voicing	25.47	(1, 27)
/u/, 90 dB SPL	voicing	28.83	(1, 27)

*$p < 0.05$.

paired groups recognized back-place consonants more accurately than either front- or mid-place consonants, as well as front-place consonants more accurately than mid-place consonants. In the manner analysis, normally hearing subjects exhibited highest scores for sibilants and lowest scores for plosives, whereas both hearing-impaired groups exhibited highest scores for nasals and glides/liquids and lowest scores for fricatives (75 dB SPL, /a/ context). These results are consistent with data reported previously for normally hearing elderly subjects (10) and for hearing-impaired listeners in a wide age range (4).

Consonant Confusions

The foregoing analysis revealed some differences in consonant recognition performance between the normally hearing and the hearing-impaired subjects, but few differences in performance between the hearing-impaired subjects with different audiometric configurations. Another source of possible differences between subject groups in consonant recognition performance is in the pattern of consonant confusions. Consonant confusions were analyzed by the individual differences scaling (INDSCAL) procedure (16) to determine whether perceptual patterns underlying consonant confusions were associated specifically with audiometric status. INDSCAL treats the frequency of observed confusions between two stimuli as an indirect indication of the perceived similarity between them. The output of INDSCAL is a "group stimulus space," which is a map of the Euclidean distances between the stimuli as derived from confusion cell frequencies. Thus, two stimuli that are frequently confused share a high cell value on the confusion matrix, and are plotted at a close distance on the group stimulus space. Multiple matrices, representing data from different conditions or subjects, are used as input to INDSCAL. The group stimulus space therefore represents the perceived distances between stimuli that are common to all conditions (or subjects) simultaneously. The group stimulus space is derived in two or more dimensions, and the appropriate dimensional solution is selected on the basis of the percentage of variance accounted for and the interpretation of the dimensions.

INDSCAL also provides a second type of output, the condition (or subject) weights. Statistically, the square of the weight value associated with a condition matrix for a dimension is the proportion of variance of that matrix accounted for by that dimension. In other words, the weights reflect the value of each dimension to each condition. Additional details of INDSCAL analysis can be found in Carroll and Chang (16) and Wish and Carroll (17).

In the present analysis, the confusion matrices of the 10 subjects in each group were pooled separately for each condition. Since each individual subject's confusion matrix in each condition represented 190 observations, each pooled matrix represented 1900 observations. A total of 18 pooled matrices resulted (three groups × two levels × three vowels), which were symmetrized (18) and used as input to the INDSCAL program of the ALSCAL-4 statistical package (19). Solutions were obtained in two through six dimensions, but the five-dimensional solution was retained for examination because it accounted for significantly more variance than the four-dimensional solution and approximately the same amount of variance as the six-dimensional solution. Further, the variance accounted for (60.2%) was comparable to that reported by other investigators (20, 21) and the dimensions were identified readily. Interpretation and labeling of the dimensions retrived by INDSCAL were made by the experimenter and not by the program.

Group Stimulus Space The five-dimensional group stimulus space derived by INDSCAL is shown in Figure 2. Previously, dimensions derived by INDSCAL from consonant confusion and consonant similarity data have been interpreted either according to phonetic features (6, 21–24) or to acoustic properties that emerge (13, 25). In the present analysis, a phonetic feature interpretation was

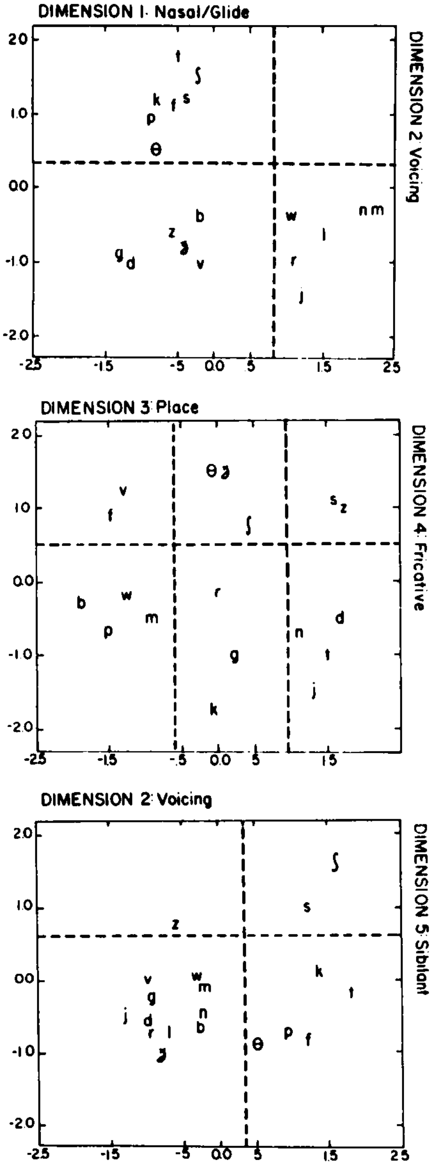

Figure 2. Group stimulus space in five dimensions derived by INDSCAL.

selected because the stimuli usually projected on each dimension in discrete clusters, with stimuli within each cluster sharing a single attribute of the feature specified. The first dimension shows a clear distinction between the nasals and glides from the other stimuli, indicating that these stimuli were not confused frequently with the remaining 13 consonants. The nasal/glide dimension could also be called sonorant. The second dimension shows a separation of voiced stimuli from the voiceless stimuli and has been labeled accordingly. The arrangement of certain phonemes on dimension 3 prohibits the identification of a clear-cut feature. However, a place feature does appear to account for the placement of most of the consonant phonemes. Specifically, front-place stimuli appear on the left side of dimension 3, whereas mid-place stimuli appear on the right side of dimension 3. Back-place stimuli (g, k, r, ʃ), and the interdentals (*θ*, ð) do not contribute to the dimensional attribute because they appear near the axis for the dimension. The projection of stimuli on dimension 4 shows that the fricatives (including the sibilant-fricatives) are separated from the other stimuli, which include nasals, glides, and plosives. Dimension 4 has been labeled fricative because of the prominence of these stimuli. Finally, dimension 5 shows that the consonant /ʃ/ is distinct from all other stimuli, and to a less extent, /s/ and /z/ are featured also. The salient characteristic attributed to sibilance therefore defines dimension 5. The dimensions defined by the present group stimulus space are highly similar to those identified previously in other studies from data of normally hearing subjects listening in quiet (6, 24) and hearing-impaired subjects listening in quiet (21) and in noise (22).

Condition Weights The main purpose of the INDSCAL analysis was to determine whether the three elderly groups with different audiometric characteristics differed in their patterns of consonant confusions. The condition weights derived by INDSCAL reveal the value of each dimension from the group stimulus space associated with each subject group in each condition, and therefore indirectly reflect possible differences among each group's consonant confusion patterns.

The weights of the three subject groups for the five dimensions of the group stimulus space in each vowel context were derived. One problem in examining the weights is whether differences in the weights among groups are statistically significant. A solution to this problem is to treat the weights associated with each vowel context and level as separate replications of the derived weights for each subject group (22). An ANOVA could then be used to examine the significance of differences in weights among groups. This would represent a conservative test because systematic differences in the weights associated with different vowel contexts and levels would tend to inflate the error term. Thus, an ANOVA was conducted on the derived weights associated with the different subject groups and dimensions, with the six conditions (level × vowel) treated as replications. Differences in weights between the subject groups were not significantly different at any dimension.

DISCUSSION

Speech recognition performance in elderly listeners is often confounded with the presence of hearing loss, which is highly variable in both degree and configuration. Moreover, most previous efforts to study speech recognition performance among elderly hearing-impaired listeners have assessed overall word recognition scores. This study separated the confounding effects of hearing loss and audiometric configuration, and evaluated patterns of consonant recognition and confusion that underlied the overall speech recognition deficits of these elderly subjects. The results revealed that consonant recognition deteriorated with the presence of hearing loss among these elderly listeners, but that unique patterns of consonant perception were not specific to the audiometric characteristics represented by our subjects. The latter finding emerges from analyses of recognition according to consonant place, manner, and voicing, and from the analyses of consonant confusions with INDSCAL. A few previous studies also found an independent relationship between consonant perceptual patterns and either hearing loss (21) or audiometric configuration (20). However, the subjects in these earlier studies were not drawn specifically from an elderly population.

The current findings contrast with those of at least one earlier study which used hearing-impaired subjects from a variety of age groups (4). The hearing-impaired subjects with gradually and sharply sloping audiometric configurations in that study were selected on the basis of nearly identical criteria to those used in this study. In terms of consonant recognition patterns, Dubno et al (4) reported that for their nonsense syllable test (NST) presented at 90 dB SPL, subjects with sharply sloping sensorineural losses performed more poorly than subjects with gradually sloping configurations for every manner and place category. In contrast, the present investigation rarely showed significant differences in performance between elderly subjects with gradually sloping and sharply sloping losses. Given that there were many methodological similarities between the two studies, a tentative conclusion is that consonant recognition patterns observed with younger hearing-impaired subjects are not characteristic of those of elderly hearing-impaired subjects with similar audiometric configurations. Possibly, the speech perception problems of elderly listeners may be of such relative magnitude that they obscure the smaller effects of differences in audiometric configuration on nonsense syllable recognition. It is also possible that nonsense syllables are not sufficiently sensitive to differences among elderly listeners with different audiometric configurations, if they exist. Another possible reason for the performance differences among groups in the current study and the Dubno et al study is that the steeply sloping loss group in that study may have had more severe impairments than the subjects in the current study. A direct comparison is difficult, however, because audiometric data were not reported by Dubno et al. However, there was one potentially important methodological difference between the two studies: Dubno et al used a +20 dB S/B, whereas this study used a +6 dB S/B. One might expect the less advantageous S/B to be sensitive to subtle differences in configuration, and thereby create observable differences in performance among the different groups. Alternatively, the more intense noise in this study could have provided more direct low frequency masking and created more upward spread of masking than the noise in the Dubno et al study.

Another potential factor that might have affected differences in performance among groups is the presence of a differential practice effect. Given that practice effects are more prominent for normally hearing listeners in difficult listening situations than in easier listening situations (26), one might hypothesize that hearing-impaired listeners experience more extensive practice effects than normally hearing listeners because the nonsense syllable task is a more difficult listening condition for the hearing-impaired listeners. Examination of practice effects was not a major aim of this study, because previous researchers (26–28) demonstrated high performance reliability with repeated presentations of closed-set nonsense syllable tests, particularly within a single presentation (26). However, Bilger and Wang (8) observed practice effects on performance with a closed-set nonsense syllable task when feedback was provided. As a basis of comparison, percent correct scores were calculated from the first five trials and second five trials of each run for each subject in each condition. The mean change in percent correct scores was +2.7% for the normally hearing listeners, +1.4% for the listeners with sharply sloping losses, and +3.1% for the listeners with gradually sloping losses. Although slight overall improvements were apparent, for some individuals in each group, scores from the second half decreased, whereas for others these scores increased. Thus, there was no apparent systematic change in performance of these elderly listeners associated with multiple presentations of this task.

A possible explanation for the performance differences among these three elderly groups is that attenuation characteristics varied among them, rather than speech perception abilities per se. This notion is confirmed by changes noted in performance with presentation level. The normally hearing subjects achieved higher scores than the two hearing-impaired subject groups at 75 dB SPL, suggesting that attenuation imposed by the hearing loss was operating for the hearing-impaired subjects. However, at 90 dB SPL, differences in acuity were less important because differences in performance were not evident between subjects with normal hearing and gradually sloping losses. The subjects with sharply sloping losses continued to be affected by the sensitivity loss at 90 dB SPL, perhaps because of the magnitude of the loss in the high frequencies. In any event, it appears that the attenuation imposed by the hearing loss primarily affected the level of performance among the different subject groups. The specific speech perception problems did not appear to be substantially different among the three groups, especially at 90 dB SPL, as reflected by the syllable recognition and confusion patterns. However, individual elderly subjects occasionally exhibited unique speech perception problems which were obscured by the analysis of group performance.

Although only a few studies have examined nonsense syllable recognition performance by elderly subjects, a consistent picture is emerging from them. Previous studies have shown that elderly listeners with relatively normal hearing recognize nonsense syllables more poorly in quiet and noise backgrounds than do young normally hearing listeners, although the specific patterns of consonant feature recognition and syllable errors tend to be comparable between the two groups (9, 10). The present study further indicates that hearing loss among elderly listeners may create additional deterioration in overall performance, but does not necessarily impose a unique pattern of speech perception performance. These findings, together with those of previous researchers, tend to support the notion that deficits in nonsense syllable recognition are common among elderly listeners, especially in noise, but that patterns specific to aging or audiometric configuration have not yet emerged among elderly listeners.

In summary, elderly hearing-impaired listeners demonstrated poorer nonsense syllable recognition in noise than elderly normally hearing listeners. Hearing-impaired listeners also exhibited poorer recognition than normally hearing listeners for consonant place, manner, and voicing. However, specific patterns of recognition performance were not markedly different between hearing-impaired subjects with gradually sloping and sharply sloping audiometric configurations. The pattern of feature weights derived from consonant confusions of the different subject groups reflected a similar trend. All subject groups showed comparable relative weightings of each dimension derived, and differences among the weights for each group were not significant. Taken together, these findings suggest that consonant recognition and confusions obtained in noise of elderly hearing-impaired subjects with gradually and sharply sloping losses may be different in degree from those of elderly normally hearing subjects. However, the confusion patterns themselves are not necessarily different in kind among these groups.

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Acknowledgments: The author expresses her gratitude to H. Timothy Bunnell for developing the software used in the project, to Stacie Raymer and Sylvia Campbell for assisting in data collection, and to Peter Fitzgibbons for his helpful suggestions during preparation of this manuscript.

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Received September 20, 1986; accepted May 15, 1987.