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Evaluation of the Use of a New Compact Disc for Auditory Perceptual Assessment in the Elderly

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Abstract

The present study examined the performance of 40 normal-hearing young adults and 38 elderly adults, some normal hearing and some hearing impaired, on the Department of Veterans Affairs' new compact disc (VA-CD) for auditory perceptual assessment. Principal-components factor analyses were performed on the test scores from each group of subjects with very similar results obtained from each group in terms of the number of factors identified (3), the percentage of variance explained by these factors individually and collectively (about 72%), and the association of various test scores with each factor. The 10 tests examined here were found to be associated with three underlying factors identified as a general speech-understanding ability (about 42% of variance), temporal sequencing capacity (about 18% of variance), and processing ability under conditions of dichotic competition (about 12% of variance). Among the elderly, hearing loss was strongly and negatively associated with general speech-recognition ability, whereas age was moderately associated with the other two factors. Test scores for several measures of auditory perceptual processing were negatively affected by the presence of peripheral hearing loss in the elderly even when administered at the highest recommended presentation level (90 dB SPL). In addition, some tests among those examined were found to have inadequate test–retest reliability for clinical use with the elderly.

Key Words: Aging, auditory processing, elderly, speech recognition

In a series of articles published in *JAAA*, the development and initial evaluation of a new compact disc (CD) designed for auditory perceptual assessment was described (Bornstein et al, 1994; Musiek, 1994; Noffsinger et al, 1994a, b, c; Wilson, 1994; Wilson et al, 1994a, b). Because the development of this CD was undertaken and supported by the Department of Veterans Affairs, the resulting test battery was referred to there, and is referred to here, as the VA-CD.

Details regarding the development of each test on the VA-CD can be obtained by consulting the original articles mentioned above. It should be noted, however, that several of the tests incorporated on the VA-CD were not specifically created by the developers of the CD but were simply re-recorded in CD format. Briefly, a total of 16 tracks on the CD are devoted to a variety of tasks designed to assess auditory processing abilities in several dimensions. Dimensions examined include binaural interaction for speech and noise masking level difference (MLD), resolution of dichotic competing speech and nonspeech sounds (dichotic chords, nonsense syllables, digits, and sentences), binaural fusion — either temporal (VIOECITO) or spectral (NU-6, high-pass and low-pass filtered), perception of temporal sequences (pitch-pattern or duration-pattern tests), and recognition of temporally degraded speech (time-compressed or compressed and reverberated NU-6 words).

The development and initial evaluation of these materials represented a major step forward in the standardization of a test battery for auditory perceptual assessment in audiology. Clinicians and researchers will undoubtedly find the availability of this collection of high-fidelity, standardized tests of benefit in assessing auditory perception in patients suspected of having

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lesions in the retrocochlear or central portions of the auditory system.

The battery of tests contained on the VA-CD may also be of value in assessing central auditory processing capabilities in individuals with no known lesions in the auditory portions of the brain stem and cortex. The test battery, for example, could be useful in applications with the elderly population. It has been suggested that the elderly may have a much higher prevalence of central auditory processing dysfunction than young adults and that this may explain much of the difficulty that the elderly have in understanding speech, either with or without a hearing aid (e.g., Stach, 1990; Stach et al, 1990). In a review of work in the area of central auditory processing disorders in the elderly, however, Humes et al (1992) suggested that many of the tests used to evaluate auditory-processing function in the elderly suffered from poor reliability or strong confounding by peripheral hearing loss. Given the high prevalence of peripheral, high-frequency, sensorineural hearing loss in the elderly, it is important that a test of non-peripheral auditory processing be unaffected by the presence of such hearing loss. It is also important that the tests used have adequate test–retest reliability. Finally, when administering batteries of tests, it is most efficient to eliminate redundant tests that assess the same basic function.

The present study evaluated the application of the VA-CD as a battery of auditory perceptual tests in a group of elderly subjects, some normal hearing and some hearing impaired, and a group of young normal-hearing subjects. Factor analyses were performed on the results from the battery to determine which tests measured the same basic perceptual function and could, therefore, be eliminated without reducing the information gained about auditory-processing abilities. Finally, most of the elderly subjects were retested either immediately or approximately 4 months after the initial test to evaluate the reliability of the measures.

METHOD

Subjects

Two groups of subjects were included in this study: 38 elderly and 40 young adults. The young adults ranged in age from 17 to 40 years with a mean age of 23.3 years. All of the young adults had normal hearing (air-conduction pure-tone thresholds < 25 dB HL [ANSI, 1989] from 250 – 8000 Hz) and normal tympanograms bilaterally. The elderly subjects ranged in age from 65 to 86 years with a mean age of 73.3 years. The hearing of the elderly ranged from normal to the presence of a moderate sloping high-frequency sensorineural hearing loss bilaterally. Mean mid-frequency (500, 1000, and 2000 Hz) pure-tone averages (PTAs) were 31.5 and 31.1 dB HL for the left and right ears, respectively, whereas mean high-frequency (1000, 2000, and 4000 Hz) PTAs were 40.3 and 39.4 dB HL in the left and right ears, respectively. The mean asymmetry in PTA was 0.5 dB for the mid-frequency average (with a standard deviation of 6.6 dB) and 0.9 dB for the high-frequency average (with a standard deviation of 7.5 dB).

Apparatus

The tests on the VA-CD were presented to groups of up to 12 subjects at a time. The output of a BSR Model MCD8090 compact disc player was routed through a Grason-Stadler Model 162 audiometer, an isolation transformer, and a power amplifier to 12 matched sets of E-A-R EARtone Model 3A insert earphones. The calibration tracks on the VA-CD were used to specify the stimulus levels (in an HA-2 2-cm^3 coupler using procedures recommended by Frank and Richards [1991]) and to confirm the appropriate phase relation between outputs from each pair of earphones.

Procedures

Of the 16 test tracks on the VA-CD, several represent alternate forms of tests. A total of 15 different auditory-processing tests are contained on the 16 test tracks of the CD. Of these, a total of 10 were evaluated in this study. Of the five tests not examined, one was not included because it did not lend itself to group testing at a fixed signal level (MLD, track 2), two were excluded because they were found in preliminary testing to be too difficult even for young normal-hearing subjects (dichotic chords—simultaneous onsets, dichotic chords—90-msec lag, tracks 3 and 4), and two were not included because of presumed redundancy with a test already included (NU-6, 45% compression + reverberation and NU-6, 65% compression + reverberation, left channel of tracks 14 – 17). That is, regarding the latter two tests, it was considered adequate to sample perception of temporally degraded speech with tests representing two different levels of one type of temporal distortion (time compression).

The remaining 10 tests of auditory perceptual processing, included in this evaluation, were as follows (original sources cited for tests that were simply re-recorded in CD format by VA-CD's developers): (1) dichotic nonsense syllables—simultaneous onsets (track 5); (2) dichotic nonsense syllables—90-msec lag (track 6; Berlin et al, 1973); (3) dichotic digits (track 7); (4) dichotic sentence identification, DSI (track 8; Fifer et al, 1983); (5) dichotic consonant-vowel segments, voice-in-one-ear-consonant-in-the-other (VIOECITO; track 9); (6) binaural NU-6, high- and low-pass filtered (track 11); (7) frequency tone patterns (track 13, left channel); (8) duration tone patterns (track 13, right channel); (9) NU-6 45 percent time compressed (track 14, right channel); and (10) NU-6 65 percent time compressed (track 16, right channel).

All materials were presented to subjects seated at individual subject stations. A presentation level of 90 dB SPL was used for all subjects so as to minimize the contributions of audibility for the hearing-impaired subjects. This level, moreover, is at the upper end of the presentation range (70–90 dB SPL) recommended by the developers of the VA-CD. Results from another group of young normal-hearing adults obtained at 70 dB SPL were consistent with those reported here for the 90-dB presentation level.

Written responses were employed for all tests and all subjects to enhance reliability. Moreover, except for the four tests making use of CVC monosyllables (VIOECITO, filtered NU-6s, NU-6s with 45% and 65% time compression), a closed-set response format was used. Written responses are not consistently recommended by the CD developers in the accompanying test manual. The test manual frequently calls for oral responses from the subject. Aside from this deviation, the instructions provided in the test manual were followed in this evaluation. The recommended protocol accompanying the VA-CD and followed here, for example, includes the presentation of five practice items for each test selected arbitrarily from the middle of a particular test track on the CD. In addition, the recommended protocol also provides for five additional monaural practice items for three of the dichotic tasks (dichotic nonsense syllables with simultaneous and lagging onsets and the DSI) prior to five binaural practice presentations.

Dichotic tests were scored without regard to ear and each stimulus was scored, rather than each trial. For example, if the subject was presented with sentence #1 to the left ear and sentence #3 to the right ear on one trial from the DSI, written responses of "1,3" or "3,1" were scored as 2 of 2 correct, whereas responses containing only a "1" or a "3" (paired with a different number) were scored as 1 of 2 correct.

Nine of the 38 elderly subjects (about 25%) were arbitrarily selected for immediate retest following a 15-minute rest period, whereas the remaining 29 were requested to return for retest approximately 4 months after the initial test. Of these 29 subjects, 20 returned for the 4-month retest. The order of test administration was identical in both sessions and progressed from lowest to highest track number for all subjects. Monaural tests (frequency and duration tone patterns and time-compressed NU-6s) were presented to the left ear for all subjects and all other tests were presented binaurally.

Approximately 60 to 75 minutes were required to complete the 10 tests examined here. All subjects were paid $10 per session for their participation.

RESULTS

Figure 1 provides the means and standard deviations for the percent-correct scores obtained from the young and elderly subjects on each of the 10 tests of the VA-CD evaluated in this study. The elderly subjects have been divided into two subgroups: (1) elderly normal hearing (ENH, N = 13) and (2) elderly hearing impaired (EHI, N = 25). The ENH subjects had mid-frequency PTAs (500, 1000, and 2000 Hz) less than or equal to 25 dB HL and high-frequency PTAs (1000, 2000, and 4000 Hz) less than or equal to 30 dB HL. The tests are listed sequentially from left to right in Figure 1 according to their track number, with the lowest track number on the left.

Several observations can be drawn from these data. First, on all but three of the tests (dichotic nonsense syllables, DichCV and DichCV90, and NU-6 with 65% time compression, NU6-65%), the mean performance of the young normal-hearing adults is approximately 90 to 100 percent. Second, the elderly subjects, regardless of hearing status, exhibit lower mean scores and higher standard deviations than the young subjects on most of these tests. In an effort to confirm these general impressions, the percentage scores were converted to proportions and arcsine transformed and then a series of 10 one-way analysis of variance (ANOVA) tests were conducted, one for each VA-CD test, to examine between-group differences in performance.

Table 1 Summary of ANOVAs and Post-hoc Scheffe Tests Examining the Effect of Subject Group on Each VA-CD Test

VA-CD Test	*ANOVA, F (df)*	*Significant Scheffe Contrasts*
DichCV	23.3 (2, 75)	YNH > ENH, EHI*
DichCV90	43.1 (2, 75)	YNH > ENH, EHI
DichDIG	34.7 (2, 75)	YNH, ENH > EHI
DSI	30.1 (2, 75)	YNH, ENH > EHI
VIOECITO	189.6 (2, 75)	YNH > ENH, EHI
NU6-Filt	90.6 (2, 75)	YNH > ENH > EHI
PitchPat	6.9 (2, 75)	YNH > ENH, EHI
DuratPat	10.2 (2, 75)	YNH > ENH, EHI
NU6-45%	90.2 (2, 75)	YNH, ENH > EHI
NU6-65%	109.6 (2, 75)	YNH, ENH > EHI

*YNH = young normal hearing; ENH = elderly normal hearing; EHI = elderly hearing impaired. Scheffe contrasts shown are significant at $p < .05$. All F values are significant at $p < .01$.

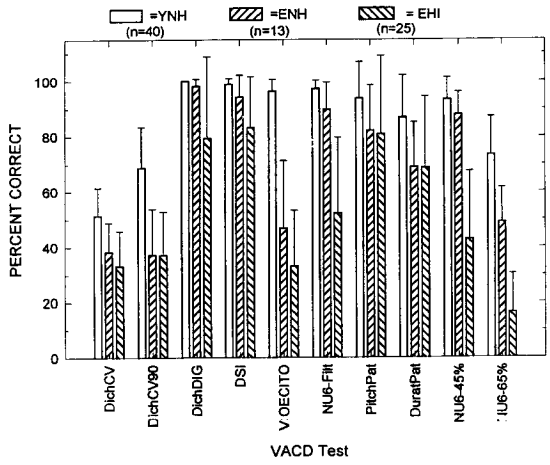

Figure 1 Means and standard deviations in percentage correct on each of the 10 VA-CD tests for three groups of subjects. For the elderly (striped bars), two subgroups have been formed: one with normal hearing (ENH) and one with hearing impairment (EHI) (YNH = young normal hearing). Thin vertical lines represent one standard deviation above the mean.

Following each ANOVA, post-hoc Scheffe tests were conducted to determine which contrasts were underlying significant effects of subject group.

Table 1 contains the details of the ANOVAs and subsequent post-hoc testing. A significant ($p < .01$) main effect of subject group was observed for every VA-CD test. The post-hoc analyses of the data revealed that the presence of a peripheral hearing loss among the elderly subjects had a negative impact on performance for 5 of the 10 tests. That is, the subgroup of elderly hearing-impaired subjects performed significantly ($p < .05$) worse than the other two subgroups on half of the tests examined in this study. The five tests that appear to be negatively affected by the presence of peripheral hearing loss (see Table 1) are (1) dichotic digits, DichDIG; (2) dichotic sentence identification, DSI; (3) filtered NU-6 word lists (NU6-Filt); (4) 45 percent time-compressed NU-6s (NU6-45%); and (5) 65 percent time-compressed NU-6s (NU6-65%). For three of the VA-CD tests (DichDIG, DSI, NU6-45%), significant differences were not observed between the YNH and ENH subjects, suggesting that there is no effect of age *per se* on these measures. For the seven remaining VA-CD tests examined in this study, however, the YNH subjects significantly outperformed both elderly subgroups (see Table 1), suggesting the presence of an age effect for these tests.

A second, and perhaps more appropriate, way to examine the influence of hearing loss on test performance among the elderly themselves is via correlational analyses. A number of correlations were performed between test performance on each of the 10 VA-CD tests and a variety of measures derived from the subjects' audiograms. Audibility measures examined included best-ear PTAs, mean binaural PTAs, and binaural asymmetry in PTAs for both the mid-frequency PTA (500, 1000, and 2000 Hz) and the high-frequency PTA (1000, 2000, and 4000 Hz). Correlations between mean binaural and best-ear mid-frequency PTA and high-frequency PTA were 0.99, indicating that they could be used equivalently. The mean binaural PTAs are used throughout the remainder of this paper. In addition, no significant ($p < .01$) correlations were observed between any of the measures of auditory perceptual processing and binaural asymmetry of the audiogram. It should be noted, however, that the subjects in this group tended to have bilaterally symmetrical hearing loss, thereby minimizing the importance of this factor.

Regarding the correlation of binaural PTAs with scores on the VA-CD tests, correlations were slightly higher for the high-frequency PTA than the mid-frequency PTA. Therefore, only the high-frequency PTA is examined in detail here. Six of the 10 correlations were significant ($p < .01$), negative, and of at least moderate strength. Scatterplots showing the association between performance on each of these six VA-CD tests and the mean binaural high-frequency PTA are provided in Figure 2. The left-hand panels in this figure show scatterplots between three VA-CD tests making use of NU-6 monosyllablic word lists, each of which is negatively

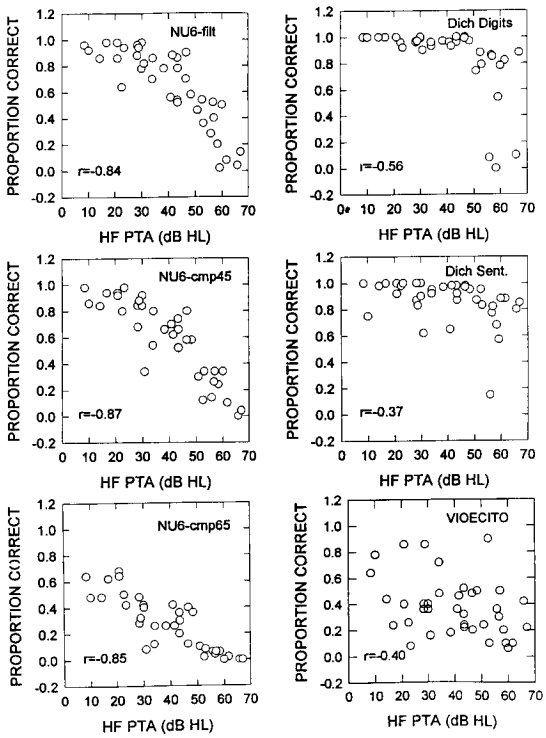

Figure 2 Scatterplots of test score (proportion correct) as a function of high-frequency pure-tone average (HFPTA) for the six VA-CD tests having significant correlations with hearing loss in the elderly (N = 38). Each panel shows the association between test score and hearing loss for a different VA-CD test with the corresponding correlation coefficient shown in the lower left corner of each panel.

correlated with the high-frequency PTA, with correlation coefficients approximating −0.85. Thus, these three measures are strongly dependent on hearing loss such that, the greater the sensorineural impairment, the poorer the performance. The three tests in the right-hand panels of this figure, all three being dichotic tests using speech stimuli, are also significantly and negatively correlated with high-frequency PTA, but the association is weaker than for the three tests in the left-hand panels. In addition, for dichotic digits (upper right) and dichotic sentence identification (middle right), there is little or no association between scores on these two tests and the high-frequency PTA for high-frequency PTAs of 50 dB HL or lower, but a considerable decline in scores is apparent as high-frequency PTA increases above 50 dB HL.

Next, to examine the redundancy among the 10 VA-CD tests investigated in this study, two principal-components factor analyses were performed on the data, one for each of the subject groups. Briefly, these analyses indicate

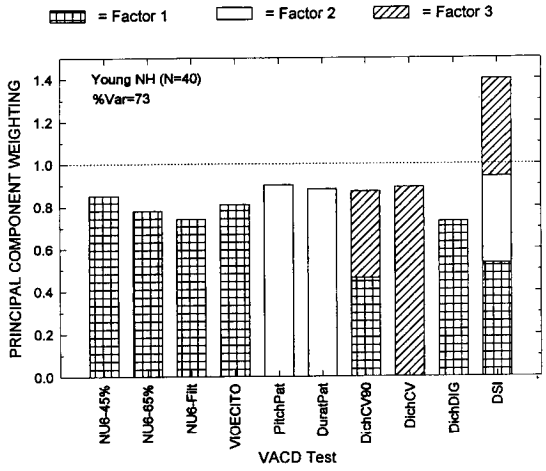

Figure 3 Results of the principal-components factor analysis for the group of 40 young normal-hearing subjects. Component weights less than 0.40 are not shown for clarity. The thin horizontal dotted line at a weight of 1.0 represents the maximum possible weighting a variable can receive on a single factor.

whether a small number of independent factors can account for significant portions of the variance in the data for each group and then identify which tests are associated with each factor (Kim and Mueller, 1990, 1991). Figure 3 illustrates the resulting factor structure when the scores on the 10 VA-CD tests for the 40 young normal-hearing listeners were subjected to principal-components analyses. A total of three factors were identified, accounting for approximately 73 percent of the variance in the data. Figure 3 plots the principal-component weighting on each of the three factors for each of the 10 VA-CD scores. Component weightings can range from 0.0 to 1.0 with the magnitude of the weight directly proportional to the strength of its association with that factor. For clarity, only component weightings above 0.4 are shown. (The complete, untruncated set of component weightings are provided in the Appendix.) Factor 1 accounted for 41.1 percent of the variance, factor 2 accounted for an additional 19.5 percent, and factor 3 accounted for an additional 12.2 percent of the variance for a total of 72.8 percent of the variance. Factor 1 is interpreted as a general speech understanding factor with some weighting of this factor on all of the speech-based tests except the dichotic nonsense syllables with simultaneous onsets (DichCV). Factor 2 is interpreted as a sequencing factor with the strongest weightings on this factor for the frequency tone pattern (PitchPat) and duration tone pattern (DuratPat) tests. The DSI is also weighted slightly on this factor. Finally, factor

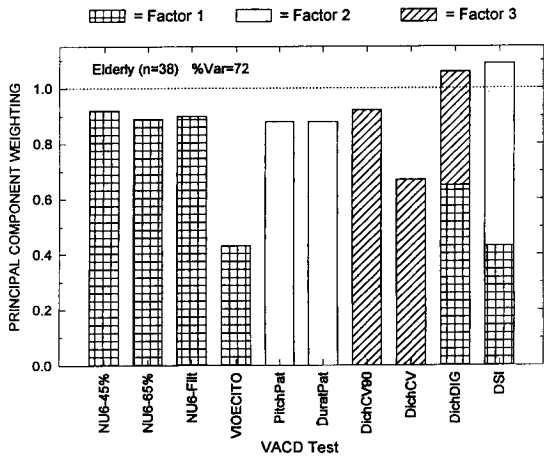

Figure 4 Results of the principal-components factor analysis for the group of 38 elderly subjects. Component weights less than 0.40 are not shown for clarity. The thin horizontal dotted line at a weight of 1.0 represents the maximum possible weighting a variable can receive on a single factor.

3 is interpreted as a dichotic competition factor with strong weighting of the dichotic nonsense syllables with simultaneous onsets (DichCV), followed by dichotic nonsense syllables with 90-msec lags (DichCV90) and the dichotic sentence identification (DSI) task.

Figure 4 reveals the results of the principal-components analysis for the data from the 38 elderly subjects. (The complete, untruncated set of component weightings are provided in the Appendix.) Three independent factors were again identified with all three accounting for approximately 72 percent of the variance in the data. The percentage of variance accounted for by factors 1, 2, and 3 was 44.4 percent, 16.4 percent, and 10.8 percent, respectively, for a total of 71.6 percent. This is very similar to the distribution of variance accounted for by each factor that was observed previously in the young normal-hearing subjects. Moreover, the weighting of each of the 10 VA-CD test scores on each of the three factors in the elderly is remarkably similar to that observed previously in the young normal-hearing subjects (see Fig. 3). In fact, the interpretations derived for the young normal-hearing subjects appear to be equally valid for the elderly, with factor 1 representing general speech understanding ability, factor 2 an auditory pattern or temporal sequencing ability, and factor 3 a dichotic competition factor.

When the principal-components analysis was repeated for the elderly subjects but with two additional variables, mean binaural high-frequency PTA and age, included, the factor structure for the 10 VA-CD tests remained virtually identical to that shown in Figure 4. However, the high-frequency PTA was strongly and negatively weighted (−0.94) only on factor 1,

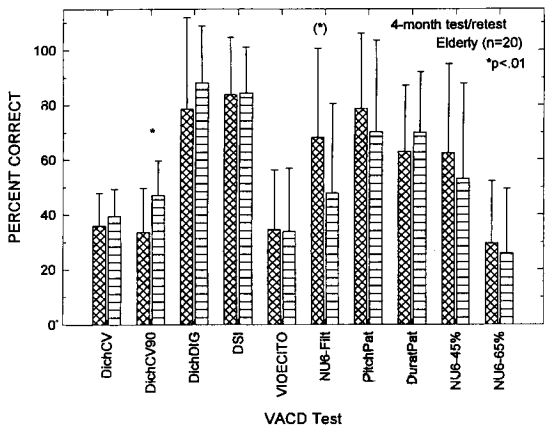

Figure 5 Means and standard deviations on each of the 10 VA-CD tests for the 20 elderly subjects retested 4 months after the initial test. Only one difference between test and retest was significant at the $p < .01$ level (*), although another difference approached significance [*], $p = .02$. Test = checkered bars and retest = striped bars. Thin vertical lines represent 1 standard deviation above the mean.

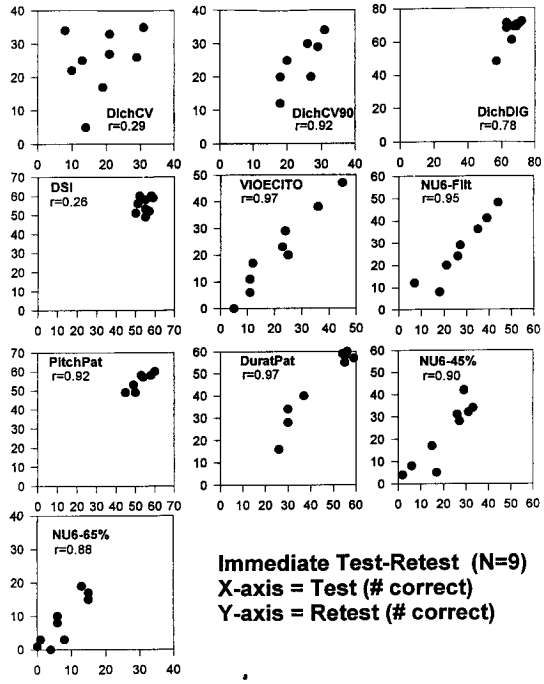

Figure 6 Scatterplots and test–retest correlation coefficients (r) for each of the 10 VA-CD tests for immediate retest. The number correct on each retest (y-axis) is plotted in each panel as a function of the number of items correct on the initial test (x-axis) with a different VA-CD test represented in each panel.

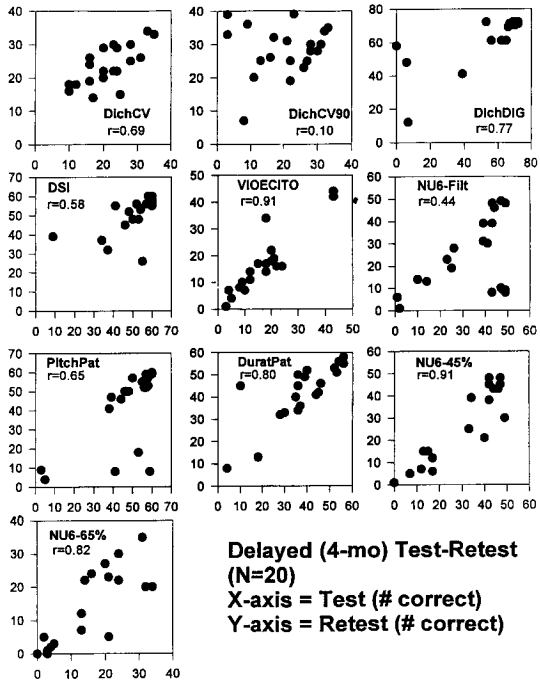

Figure 7 Scatterplots and test–retest correlation coefficients (r) for each of the 10 VA-CD tests for delayed (4-month) retest. The number correct on each retest (y-axis) is plotted in each panel as a function of the number of items correct on the initial test (x-axis) with a different VA-CD test represented in each panel.

indicating that hearing loss was strongly and inversely related to general speech understanding ability. Further, the age variable was not heavily weighted on factor 1, but was on the other two factors. Age was weighted 0.49 on factor 2, implying a positive association between age and temporal-sequencing abilities, whereas age was weighted −0.53 on factor 3, indicating a moderate negative association between age and dichotic-competition skills.

Regarding the test–retest reliability of the 10 VA-CD tests examined in this study, two types of analyses were performed: repeated measures ANOVAs and test–retest correlations. None of the repeated-measures ANOVAs on the test and retest scores for the immediate retest ($N = 9$) were significant ($p > .05$). For the 4-month retest interval, the results are shown in Figure 5. The vertical bars represent mean test and retest performance on each of the 10 VA-CD tests. The only significant ($p < .01$) difference between test and retest at the 4-month retest interval occurred for dichotic nonsense syllables with 90-msec lag (DichCV90), although the test–retest difference for the filtered NU-6 test approached significance ($p = .02$).

With regard to test–retest correlations for each of the 10 tests of the VA-CD evaluated here, Figures 6 and 7 display scatterplots and the test–retest correlations for the immediate retest and the 4-month retest for the elderly subjects, respectively. As would be expected, the correlations are higher for the immediate retest as compared to the 4-month retest. In addition, while it is clear that several tests have high test–retest correlations, it is also apparent that some other tests do not. Often, test–retest correlations under 0.90 are considered unacceptable, especially for immediate retest conditions, with 0.8 frequently considered to be an absolute minimally acceptable test–retest correlation. At least two tests (dichotic nonsense syllable with simultaneous onset, DichCV, and DSI) have unacceptably low test–retest correlations for both immediate and delayed retest. It is possible, however, that the low test–retest correlation for the DSI under immediate retest conditions (see Fig. 6) is due to the high and restricted set of scores obtained on this test by these nine subjects, although other tests with a comparable range of scores (DichDIG and PitchPat) reveal high test–retest correlations ($r > 0.8$) in these same subjects.

DISCUSSION

Comparisons of the present data to previous results for young normal-hearing subjects are difficult in that the series of articles in this journal describing normative performance for several of the tests on the VA-CD did not always provide data for this group at the maximum recommended level of 90 dB SPL. Nonetheless, the present results appear to be consistent with the norms previously published in this journal by Noffsinger and colleagues. The only possible exception to this may be for the dichotic nonsense syllables with simultaneous onsets. Whereas Noffsinger et al (1994) had observed a mean score of approximately 60 percent on this test when administered at 90 dB SPL, the present results more closely approximated 50 percent for a comparable set of subjects and conditions.

The preceding results have some significant implications for the use of the VA-CD as a measure of auditory perceptual processing abilities in elderly listeners. First, of the 10 tests examined in this study, at least two were found to have questionable test–retest reliability: dichotic nonsense syllables with simultaneous onsets (track 5) and DSI (track 8). Poor reliability of the DSI had been observed previously (Cokely

and Humes, 1992). Neither the DSI nor the dichotic nonsense syllables with simultaneous onsets should be used to evaluate auditory perceptual processing in the elderly. Results obtained with these tests in this population are simply too unreliable. It does not appear to be the case, moreover, that more extensive practice would be of benefit for these tests. Recall, for instance, that the repeated-measures ANOVAs conducted on the immediate retest data failed to find any significant changes in performance from test to retest. If additional practice is an important consideration, then these data suggest that administering each test twice, with the first presentation discarded as practice, will not change the measured performance on each test. Of course, it is possible that even greater amounts of practice would prove beneficial, but not without severe costs in additional administration time for the tests. Finally, the principal-components analyses indicate that both of these tests are redundant with other, more reliable measures that are also unaffected by the presence of high-frequency sensorineural hearing loss.

Of the remaining eight VA-CD tests evaluated in this study, four were strongly affected by the presence of high-frequency sensorineural hearing loss. Given the high prevalence of such hearing loss among the elderly, it is questionable whether any of these four tests can be counted on to provide an audibility-independent measure of auditory perceptual processing ability in the elderly. The confounding of VA-CD test peformance with peripheral hearing loss was observed in this study, moreover, despite use of the highest presentation level recommended by the VA-CD developers (90 dB SPL). The negative influence of hearing loss on test performance is only likely to increase with even lower presentation levels.

The principal-components analyses revealed that a robust factor structure was apparent for both subject groups and that the nature of this structure was virtually identical in both age groups. Not only were three factors identified in each group, but the weightings of each test score on the three factors were essentially equivalent. This suggests that the 10 VA-CD tests (eight after discarding the two unreliable measures) could be reduced to three tests, one strongly associated with each independent underlying factor, without a loss of significant information about the underlying auditory-processing capabilities assessed with the VA-CD. That is, only three tests are needed to represent the three auditory perceptual processing abilities underlying this battery of tests: one test of general speech-understanding ability, one test of temporal sequencing, and one test of processing ability under conditions of dichotic competition. Considering the underlying factor structure, the test–retest reliability, and the confounding effects of sensorineural hearing loss all together, the following three tests are recommended as an appropriate battery for auditory perceptual evaluation of the elderly when administered at 90 dB SPL (70 dB HL): VIOECITO (factor 1), tone duration pattern (factor 2), and dichotic nonsense syllables with 90-msec lag (factor 3). If it is known that the elderly subject has a high-frequency PTA of 30 dB HL or less in both ears, then the time-compressed or binaural filtered NU-6 materials could be substituted for measures of factor-1 ability in place of VIOECITO. Finally, this reduced set of three VA-CD tests might be used as a first screen for processing deficits in the elderly and, if low scores are observed, followed by administration of some of the other redundant tests in the battery that tap the same ability and thereby improve the reliability of the clinical assessment.

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APPENDIX

An untruncated set of principal-component weightings for each of three factors associated with analysis of VA-CD scores from young normal-hearing subjects in Figure 4 is presented below. Only values > .39 appear in Figure 4.

Variable	*Factor 1*	*Factor 2*	*Factor 3*
DichCV	−.05	.08	.89
DichCV90	.46	.34	.41
DichDIG	.73	−.30	.18
DSI	.53	.41	.46
VIOECITO	.81	.02	.36
NU6-Filt	.74	.21	.09
PitchPat	.19	.90	−.07
DuratPat	−.04	.88	.37
NU6-45%	.85	.12	−.16
NU6-65%	.78	.26	−.24

An untruncated set of principal-component weightings for each of three factors associated with analysis of VA-CD scores from elderly subjects in Figure 5 is presented below. Only values > .39 appear in Figure 5.

Variable	*Factor 1*	*Factor 2*	*Factor 3*
DichCV	.20	.28	.67
DichCV90	.13	.07	.92
DichDIG	.65	.25	.41
DSI	.43	.66	.17
VIOECITO	.43	−.28	.21
NU6-Filt	.90	.06	.24
PitchPat	.12	.81	.23
DuratPat	.02	.86	.08
NU6-45%	.92	.23	.14
NU6-65%	.89	.21	−.02