Normative Data for the Maryland CNC Test

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Abstract

Background: The Maryland consonant-vowel nucleus-consonant (CNC) Test is routinely used in Veterans Administration medical centers, yet there is a paucity of published normative data for this test.

Purpose: The purpose of this study was to provide information on the means and distribution of word-recognition scores on the Maryland CNC Test as a function of degree of hearing loss for a veteran population.

Research Design: A retrospective, descriptive design was conducted.

Study Sample: The sample consisted of records from veterans who had Compensation and Pension (C&P) examinations at a Veterans Administration medical center (N = 1,760 ears).

Data Collection and Analysis: Audiometric records of veterans who had C&P examinations during a 10 yr period were reviewed, and the pure-tone averages (PTA4) at four frequencies (1000, 2000, 3000, and 4000 Hz) were documented. The maximum word-recognition score (PB_{max}) was determined from the performance-intensity functions obtained using the Maryland CNC Test. Correlations were made between PB_{max} and PTA4.

Results: A wide range of word-recognition scores were obtained at all levels of PTA4 for this population. In addition, a strong negative correlation between the PB_{max} and the PTA4 was observed, indicating that as PTA4 increased, PB_{max} decreased. Word-recognition scores decreased significantly as hearing loss increased beyond a mild hearing loss. Although threshold was influenced by age, no statistically significant relationship was found between word-recognition score and the age of the participants.

Conclusions: Results from this study provide normative data in table and figure format to assist audiologists in interpreting patient results on the Maryland CNC test for a veteran population. These results provide a quantitative method for audiologists to use to interpret word-recognition scores based on pure-tone hearing loss.

Key Words: Compensation and pension, standard deviation, Maryland CNC Test, performance-intensity function, phonemically balanced, rationalized arcsine transform, validity, word familiarity, word recognition

Abbreviations: C&P = Compensation and Pension; CNC = consonant-vowel nucleus-consonant; PB_{max} = maximum word-recognition score; PI = performance-intensity; PTA = pure-tone average; PTA4 = pure-tone average at 1000, 2000, 3000, and 4000 Hz; rau = rationalized arcsine transform unit; SD = standard deviation; SSI_{max} = maximum sentence recognition for synthetic sentences

INTRODUCTION

Measures of speech perception are an essential component in the evaluation of a patient's hearing ability. Speech perception assessment is basic to almost every aspect of audiology, including its research and theoretical foundations, the fundamental understanding of how the ear functions, and the clinical administration of diagnostic and rehabilitative services for patients with hearing problems (Mendel and Danhauer, 1997). Clinicians evaluate their patients' speech perception capabilities in order to help diagnose patients'

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hearing problems differentially and to find appropriate intervention treatments and methods that will ultimately improve upon those speech perception skills. The focus of this study was to provide information that is of value in the interpretation of word-recognition scores for a veteran population.

The Maryland consonant-vowel nucleus-consonant (CNC) Test (Causey et al, 1984) is an open-set word-recognition task used by the Department of Veterans Affairs (VA) as part of the audiological Compensation and Pension (C&P) examination. The audiology C&P examination is an essential component in the evaluation of a claim for hearing disability related to military service. The Compensation and Pension Manual (Veterans Administration, 2012) states that "impaired hearing will be considered to be a disability when the auditory threshold in any of the frequencies 500, 1000, 2000, 3000, 4000 Hertz is 40 decibels or greater; or when the auditory thresholds for at least three of the frequencies 500, 1000, 2000, 3000, or 4000 Hertz are 26 decibels or greater; or when speech recognition scores using the Maryland CNC Test are less than 94 percent." Once it has been determined that a hearing disability is present, the average of the pure-tone thresholds at 1000, 2000, 3000, and 4000 Hz (PTA4) and maximum word-recognition score (PB_{max}) will be used to determine the degree of disability. However, on occasion the audiologist providing the C&P examination may believe that the combined use of pure tones and speech-recognition scores is inappropriate for rating purposes. This could occur as a result of foreign language background; speech, language, or cognitive disorders; or poor intertest reliability. In such cases, with appropriate certification, only the pure-tone thresholds, if deemed valid, would be used to determine degree of disability.

Although the Maryland CNC Test has been used as part of audiological C&P examinations in all VA facilities for a number of years, few published normative data are available to assist audiologists in determining what the expected scores on this test should be for individuals with varying degrees of hearing loss. Such information about the means and distribution of word-recognition scores as a function of degree of hearing loss is necessary for appropriate interpretation of test results. For example, a word-recognition score that is disproportionately low in comparison to the degree of hearing loss has potentially significant clinical implications regarding the possibility of a retrocochlear site of lesion that may require further testing and a possible medical referral. Should an unexpectedly low PB_{max} score occur during a C&P examination, the audiologist may decide to recommend that the rating be based on pure-tone thresholds alone. Thus, audiologists must be familiar with the range of word-recognition scores that is expected for a particular degree of hearing loss to allow them to better understand the relationship between speech perception and hearing sensitivity and subsequently make appropriate clinical decisions regarding additional diagnostic testing that may be needed and/or recommendations regarding audiological rehabilitation.

Over the years, studies have established normative data on word-recognition test materials with various populations so that audiologists can be confident in the judgments of their patients' scores relative to the magnitude of hearing loss (e.g., Dubno et al, 1995; Yellin et al, 1989). In addition, researchers have published germinal articles on how performance on clinical tests of speech perception can be interpreted by using a statistical model based on binomial theory (Thornton and Raffin, 1978; Raffin and Thornton, 1980; Carney and Schlauch, 2007). Such a binomial model provides a theoretical framework for deriving a practical method for evaluating significant differences in word-recognition scores on consecutive tests, with the assumption that responses to test stimuli are independent of each other. Thus, the binomial model assists in the interpretation of an individual's score in relationship to the means and distribution of published normative data.

The Maryland CNC Test consists of stimuli from Lehiste and Peterson's phonemically balanced word lists, all of which were CNC monosyllables (Lehiste and Peterson, 1959). These CNC lists were balanced so that each initial consonant, each vowel, and each final consonant appeared with the same frequency within each list. The authors later revised these CNC lists to eliminate some relatively rare literary words and proper names, resulting in 10 revised CNC lists of 50 phonemically balanced word lists (Peterson and Lehiste, 1962).

Causey et al (1984) used Peterson and Lehiste's revised CNC word lists to develop the Maryland CNC Test. The authors modified the word lists to include the effects of coarticulation, where the acoustic properties of phonemes are influenced by those phonemes that immediately precede and follow them. Each stimulus word was therefore embedded in the phrase, 'Say the ___ again,' and recorded by a male speaker. Performance-intensity (PI) functions were measured on participants with normal hearing and those with sensorineural hearing loss; the participants with hearing loss were all male veterans ranging in age from 30–74 yr. Causey et al (1984) also evaluated the Maryland CNC Test to determine PI functions for listeners with normal hearing and to determine the PI functions, interlist equivalence, and test-retest reliability in participants with hearing loss. The results indicated that participants with hearing loss had a wide range of scores on the Maryland CNC Test at each presentation level, suggesting the capacity for differentiation among individuals with varying degrees of hearing loss using this test. Causey and colleagues also concluded that only lists 1, 3, 6, 7, 9, and 10 had interlist equivalence for the measurement of word-recognition ability (Causey et al, 1984).

Yellin et al (1989) provided the basis for the design of the study described here, although we recognize that Yellin et al (1989) did not study a veteran population. Nonetheless, portions of their methodology were appropriate for use in the present study. Yellin et al retrospectively analyzed the audiometric records of patients with sensorineural hearing loss to provide normative values for (1) the PB_{max} for PAL-PB 50 words and (2) the SSI_{max} (Synthetic Sentence Index), or the peak of the PI function for synthetic sentences. Results revealed that PB_{max} correlated best with the PTA at 1000, 2000, and 4000 Hz, whereas SSI_{max} correlated best with the PTA at 500, 1000, and 2000 Hz.

In the present study, normative values for the Maryland CNC Test were determined using methods similar to those used by Yellin et al (1989). The purpose of this study was to provide information on the means and distribution of word-recognition scores on the Maryland CNC Test as a function of degree of hearing loss for a veteran population. Our results provide audiologists with quantitative data to assist in their interpretation of their patients' speech perception performance on this test.

METHOD

Study Sample

Audiometric records of veterans (aged 20–93 yr, M = 52 yr) who had audiological C&P examinations at a Veterans Administration medical center during a 10 yr period were reviewed retrospectively. Each participant's right and left ear air conduction thresholds were categorized separately based on the PTA at 1000, 2000, 3000, and 4000 Hz (PTA4). This four-frequency PTA was used instead of the traditional three-frequency PTA (500, 1000, and 2000 Hz) in order to reflect the frequencies used in the rating of service connected disability for veterans (Veterans Administration, 2012). The rationale was to compare word-recognition performance to the pure-tone frequencies that contribute most to speech perception. Categories of hearing loss, based on PTA4, were divided into 10 dB ranges according to the following criteria: normal hearing = PTA4 ≤20 dB HL; mild hearing loss = PTA4 of 21–30 dB HL; mild-moderate hearing loss = PTA4 of 31–40 dB HL; moderate hearing loss = PTA4 of 41–50 dB HL; moderate to severe hearing loss = PTA4 of 51–60 dB HL; severe hearing loss = PTA4 of 61–70 dB HL; and severe to profound hearing loss = PTA of 71–80 dB HL, PTA4 of 81–90 dB HL, and PTA4 >90 dB HL. Table 1 shows the number of ears for each hearing category for a total of 1760 ears along with mean age in years.

Procedure

We followed established procedures for administering an audiological C&P examination using a battery of audiometric measures including immittance tests, pure-tone audiometry by air and bone conduction, and speech audiometry. Audiometric records of all veterans who had C&P examinations during a 10 yr period were reviewed, and audiometric thresholds and PTA4 were documented. Immittance results had to reflect normal middle ear function at the time of testing in order for the data to be used in the statistical analysis. PI functions were obtained using a compact disc recording (VA, *Speech Recognition and Identification Materials, Disc 1.1*, VA) of the Maryland CNC Test (Causey et al, 1984). The procedure for determining the PB_{max} described below was used for all examinations reviewed for this study.

First, we obtained the initial word-recognition score using one 50-word list of the Maryland CNC Test (Lists 1, 3, 6, 7, 9, or 10) at a presentation level of 40 dB sensation level re: speech recognition threshold. The initial presentation level was adjusted to be at least 5 dB above the air conduction threshold at 2000 Hz, but not above the patient's tolerance level. If the initial test of word recognition produced a score of less than 94%, a PI function was obtained using half-lists presented at 6 dB above and 6 dB below the initial presentation level. If the word-recognition score did not improve by at least 6 percentage points, the initial word-recognition score using the 50-word list was reported as PB_{max}. If the word-recognition score improved by at least 6 percentage

Table 1. Number of Ears and Age in Years across Hearing Loss Category (N = 1760)

Hearing Category (dB HL)	Number of Ears	Percent (%) of Ears	Mean Age (yr)	Age (yr) Min-Max
Normal (≤20)	677	38.5	40	20–78
Mild (21–30)	148	8.0	51	20–78
Mild-Moderate (31–40)	188	11.1	52	22–80
Moderate (41–50)	243	13.8	56	26–93
Moderate to Severe (51–60)	246	14.0	62	22–86
Severe (61–70)	136	7.7	65	21–87
Severe to Profound (71–80)	80	4.5	65	23–84
Severe to Profound (81–90)	19	1.1	66	45–80
Severe to Profound (>90)	23	1.3	71	52–85
Total Ears	1760	100	52	20–93

points, we obtained another score using a 25-word list at an additional 6 dB increment. This procedure was continued until no further improvement of 6 percentage points or greater was noted. Finally, a full 50-word list was presented at the level of maximum performance and was reported as PB_{max}.

As an example, if an initial word-recognition score of 80% was obtained using a 50-word list presented at a level of 50 dB HL, then the presentation level was increased to 56 dB HL and a 25-word list was presented at this level. If the score increased to 88% (8 percentage-point improvement), then the presentation level was increased to 62 dB HL and another 25-word list was presented at this level. If the score decreased to 84% (4 percentage-point reduction), then the presentation level was reduced to 44 dB HL and another 25-word list was presented. If the score at this level (6 dB below original presentation) was less than 88%, the presentation level was set back to 56 dB HL and a 50-word list was presented. The score obtained using the full list at the optimum presentation level was estimated to be the PB_{max}.

Data Analysis

The PB_{max} percent correct scores were converted to rationalized arcsine transform units (raus) before data analysis (Studebaker, 1985). The rau, like the arcsine transform, increases the homogeneity of variance and helps deal with ceiling effects by generating numbers that are equivalent to percent correct over a wide range of approximately 15–85%. The PB_{max} percent scores were converted because raus can minimize the relationship between the mean score and the variance that is characteristic of percentage scores and, at the same time, provide a scoring unit that is similar to percentage and can therefore be readily interpreted. The term *PB_{max} rau* is used here to describe the best word-recognition score obtained for each ear using a full, 50-item Maryland CNC list. After data analysis was complete, all scores were reverse transformed and provided as percent correct values for clinical application.

In order to be included in the statistical analysis, we needed the following information from each ear: (1) participants' age (2) PTA4 (pure-tone air conduction thresholds at 1000, 2000, 3000, and 4000 Hz), and (3) PB_{max} as determined by the procedure described above. No ears with conductive hearing losses (i.e., air-bone gaps ≥10 dB) and/or abnormal tympanograms were included in the sample. Nonlinear regression analyses were used to determine if the variables of PTA4 and age had significant influences on word-recognition scores. Correlations were calculated between the mean PB_{max} rau and the PTA4 across the hearing loss categories to determine the effect of hearing on word recognition for the Maryland CNC Test.

RESULTS

Effects of Hearing Loss and Age on PB_{max}

Individuals with hearing loss who have similar audiograms frequently experience varying degrees of communication problems often as a result of the effects that different underlying pathological conditions can have on one's speech perception ability. Therefore, it was important to verify that treating each ear as a separate entity was not influenced by such potential confounding factors. Nonlinear regressions were conducted comparing PTA4 and PB_{max} rau using the entire sample that treated each ear as a separate entity (r = –0.69) and for all left ears (r = –0.69) and all right ears (r = –0.68). Given that no difference was seen when comparing right and left ear performance with individual ear performance, the remaining analyses were conducted on the entire sample treating each ear as a separate entity (N = 1760).

Nonlinear regression analyses were used to determine if the independent variable of PTA4 had a significant influence on word-recognition scores. The regression analysis was first run separately on all ears with normal hearing and all ears with hearing loss. A significant negative correlation was found between PB_{max} rau and PTA4 for normal ears ($r = -0.18, p < 0.001$). There was a stronger significant negative correlation between PB_{max} rau and PTA4 for ears with hearing loss ($r = -0.67, p < 0.001$) indicating that PB_{max} rau decreased as the PTA increased; that is, word-recognition scores decreased as the amount of hearing loss increased. Forty-six percent of the variance in PB_{max} rau scores was explained by PTA4 for ears with hearing loss ($R^2 = 0.46$). However, for normal ears, only 3.5% of the variance in PB_{max} rau scores could be explained by PTA4 ($R^2 = 0.035$). The nonlinear regression was repeated for all normal-hearing and hearing-impaired ears as a group, indicating a statistically significant negative correlation between PB_{max} rau and PTA4 ($r = -0.68, p < 0.001$). Forty-seven percent of the variance in PB_{max} rau scores was explained by PTA4 for all ears ($R^2 = 0.47$). The PB_{max} rau scores were reverse transformed to percent correct and are displayed as a scatterplot in Figure 1 for all ears showing that word recognition decreased as PTA4 increased.

Nonlinear regression analyses were also used to determine if the independent variable of age had a significant influence on word-recognition scores. Regression results showed no statistically significant relationship between age and word recognition ($r = 0.02, p = 0.38$), suggesting that age did not have a significant influence on word-recognition score for this sample. The PB_{max} rau scores were reverse transformed to percent correct and are displayed as a scatterplot in Figure 2 for all

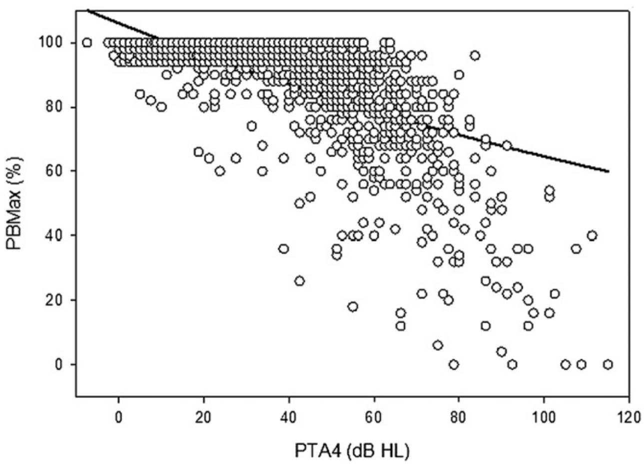

Figure 1. Nonlinear regression analysis displaying PB_{max} (percent correct) as a function of PTA4 (1000, 2000, 3000, and 4000 Hz) in dB HL for all ears with normal hearing and hearing loss (r = –0.68, $p < 0.001$).

ears showing a wide range of PB_{max} rau scores associated with increases in age. When PTA4 and age were compared, statistical analyses did show a significant relationship between the two variables ($r = 0.65$, $p < 0.001$), providing evidence that although word-recognition scores were not affected by age, higher thresholds were associated with older age. This relationship is evident in Table 1.

Means and Distribution of Word-Recognition Scores

The primary purpose of this study was to document the range of word-recognition scores for PB_{max} obtained on the Maryland CNC Test for varying degrees of hearing loss in a veteran population. Documenting the range of word-recognition scores provides normative data for clinical audiologists to use when interpreting word-recognition scores on the Maryland CNC Test. Table 2 shows the mean PB_{max} percent correct scores with ±1 standard deviation (SD) for the eight hearing loss categories as well as ears with normal hearing along with the range of scores, medians, and first and third quartiles. A wide range of scores is present for each hearing category with a PTA4 greater than 50 dB HL, and the SDs increase as the level of hearing loss increases. The smallest variance was observed for the normal listeners (PTA4 ≤20 dB HL) and the mild hearing loss group (PTA4 = 21–30 dB HL), and the greatest variance was observed for the participants with PTA4 worse than 60 dB HL.

The data from Table 2 are also plotted in Figure 3, which displays box plots for each hearing loss category as well as the normal-hearing category. The mean and median PB_{max} scores in percent correct are plotted within each box plot along with the first and third quartiles. SDs are also plotted in this figure.

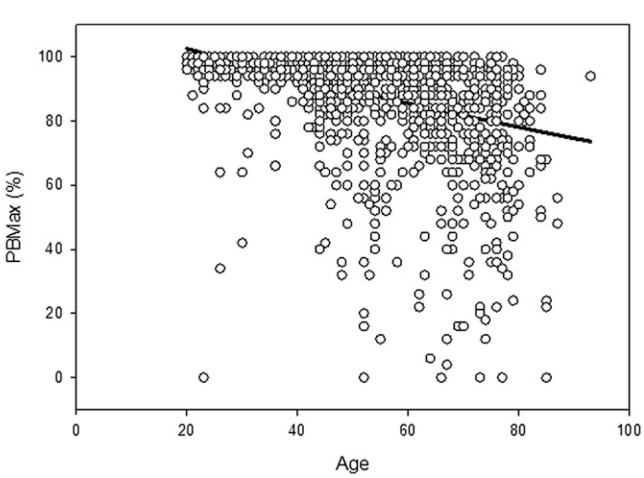

Figure 2. Nonlinear regression analysis displaying PB_{max} (percent correct) as a function of age for all ears with normal hearing and hearing loss ($r = 0.02$, $p = 0.38$).

DISCUSSION

The purpose of this retrospective study was to provide normative data for a veteran population for the Maryland CNC Test in order to assist audiologists in interpreting patient results and formulating impressions about speech perception performance. Word-recognition scores decreased significantly as hearing loss increased beyond a mild hearing loss as evidenced by the strong, significant negative correlation between PB_{max} and PTA4. This relationship between word recognition and hearing loss was not unexpected and confirms that the Maryland CNC Test is capable of documenting that word recognition is negatively affected by decreased hearing sensitivity. We also found considerable variability in scores for various levels of hearing loss, which justifies the need to consider both threshold and word-recognition score when evaluating a claim for hearing disability related to military service.

We also investigated whether there was a significant relationship between word-recognition scores and the age of the participants in this study. Previous studies have shown that age and temporal processing influence speech understanding in fluctuating backgrounds in adults with normal hearing or mild high-frequency sensorineural hearing loss (Snell and Frisina, 2000). In addition, Pichora-Fuller (2003) found age-related differences in cognitive performance during spoken language comprehension.

In the present study, we did not find a statistically significant relationship between age and word recognition across the ears with normal hearing or those ears with hearing loss. The regression analyses showed that little additional variance in PB_{max} rau scores, over and above that explained by threshold, could be accounted for by age. Yet, we did measure a correlation between

Table 2. Mean PB_{max} Percentage Scores with ±1 SD for the Normal-Hearing Ears and all Hearing Loss Categories Using PTA4

PTA4 (dB HL)	N	Mean	SD	Range of Scores (%)	Median	25% Quartile	75% Quartile
≤20	677	97.17	3.11	94–100	98	96	100
21–30	148	95.71	5.10	91–100	96	94	98
31–40	188	94.10	6.42	88–100	94	94	96.5
41–50	243	90.77	9.06	82–100	94	88	96
51–60	246	85.37	13.87	71–99	88	79.5	94
61–70	136	69.78	20.48	49–90	80	70	88
71–80	80	60.46	21.80	39–82	64	48	76
81–90	19	51.05	20.85	30–72	49	37	67
>90	23	27.22	19.82	7–47	23	13	39

Note: Median values and 25% and 75% quartiles are also shown.

threshold (PTA4) and age, suggesting that higher thresholds were associated with older age. One would expect to see a relationship between age and threshold, yet it is surprising that the addition of age did not produce a significant increase in explained variance for the word-recognition scores obtained here.

It is likely that age had no measurable effect in this study primarily because there was such a wide range of ages within each hearing category. Table 1 shows that the ages within each category varied considerably, which likely minimized the ability for a statistical difference to be measured across the groups. Furthermore, age had little measurable effect because of the relatively low mean age (52 yr) of the participants in this sample.

The range and distribution of scores reported here should improve the audiologist's ability to interpret results obtained from the Maryland CNC Test. Although the precision for computing standard errors might be somewhat limited because we used individual ears as independent data points, we believe that the large data set analyzed here accurately reflects the range and distribution of scores on the Maryland CNC Test. Caution should be exercised, however, in generalizing these findings to other speech perception materials and other populations. As noted by Yellin et al (1989) and Mendel and Danhauer (1997), the normative data reported here are specific to the particular speech material used (in this case, the Maryland CNC Test). Additional data are needed if generalizations are to be made to other speech perception materials and other populations. Furthermore, these findings are limited because of the particular method used here to determine PB_{max}. However, these normative data should be useful for others using the Maryland CNC Test with a veteran population.

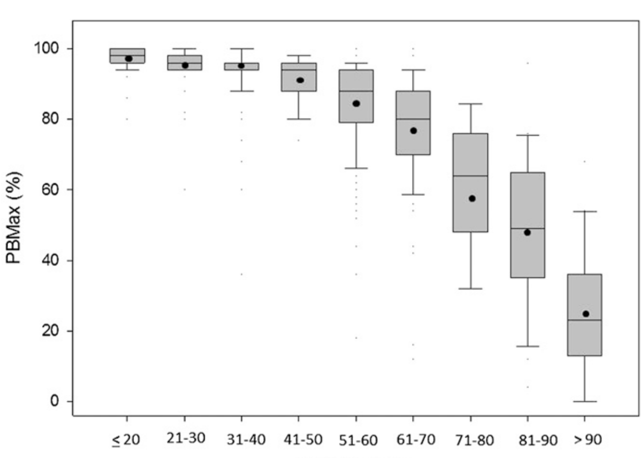

Figure 3. Mean PB_{max} (percent correct) as a function of PTA4 (dB HL) with means (filled circles), ±1 SD (cross hairs), medians (horizontal lines), and first and third quartiles (areas above and below the medians) for all ears with normal hearing and hearing loss.

CONCLUSIONS

The results of this study provide normative data concerning the relationship between a word-recognition score on the Maryland CNC Test and pure-tone hearing sensitivity for a veteran population. These results provide a quantitative method for audiologists to use to interpret word-recognition scores for varying degrees of pure-tone hearing loss.

Word-recognition scores decreased significantly as hearing loss increased beyond a mild hearing loss. In addition, no significant relationship was found between word-recognition scores and age, yet we did find a correlation between pure-tone threshold and age. The range of word-recognition scores for varying degrees of hearing loss was documented, along with means, SDs, medians, and first and third quartiles of performance. Clinicians can use the data provided in Table 2 and Figure 3 to help interpret word-recognition scores obtained using the Maryland CNC Test.

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