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Dichotic Digits Test Performance Across the Ages: Results From Two Large Epidemiologic Cohort Studies

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Abstract

Objectives—The Dichotic Digits Test (DDT) has been widely used to assess central auditory processing but there is limited information on observed DDT performance in a general population. The purpose of the study was to determine factors related to DDT performance in a large cohort spanning the adult age range.

Design—The study was cross-sectional and subjects were participants in the Epidemiology of Hearing Loss Study (EHLS), a population-based investigation of age-related hearing loss, or the Beaver Dam Offspring Study (BOSS), a study of aging in the adult offspring of the EHLS members. Subjects seen during the 4th EHLS (2008-2010) or the 2nd BOSS (2010-2013) examination were included [N = 3655 participants (1391 EHLS, 2264 BOSS); mean age = 61.1 yrs, range = 21-100 yrs]. The free and right ear directed recall DDTs were administered using 25 sets of triple-digit pairs with a 70 dB HL presentation level. Pure-tone audiometric testing was conducted and the pure tone threshold average (PTA) at 0.5,1,2 and 4 kHz was categorized using the worse ear: No Loss = PTA ≤25 dB HL; Mild Loss = 25 < PTA ≤40 dB HL; Moderate or Marked Loss = PTA > 40 dB HL. Cognitive impairment was defined as a Mini-Mental State Examination score < 24 (maximum = 30) or a self- or proxy-reported history of dementia or Alzheimer's disease. Demographic information was self-reported. General linear models were fit and multiple linear regression was performed.

Results—The mean total free recall DDT score was 76.7% (range = 21.3%-100%). Less than 10% of the participants had a total free recall score below 60% correct. The mean right ear

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M.E.F., K.J.C., D.M.N. developed the study concept, analyzed data, and interpreted the results. M.E.F., K.J.C., D.M.N., B.E.K.K., R.K., T.S.T., D.S.D, and A.J.P. were involved in the acquisition of subjects and/or data. M.E.F. drafted the article and all authors reviewed and provided comments on the submitted manuscript.

directed recall score was 98.4% with 69% of the participants scoring 100% and another 15.5% scoring 98.7% (1 incorrect digit). In multivariable modeling of the total free recall scores, the predicted mean free recall score was 1 percentage point lower for every 5 year increase in age, 2.3 percentage points lower in males than females, 8.7 percentage points lower in participants with less than a high school degree than in those with college degrees, 6.8 percentage points lower in participants with a moderate or marked hearing loss compared with no hearing loss, and 8.3 percentage points lower in participants with cognitive impairment compared with those without cognitive impairment. These 5 factors were independently and significantly related to performance and accounted for 22.7% of the total variability in free recall scores.

Conclusions—Substantial variation in the total free recall DDT scores but very little variation in the right ear directed recall DDT scores was observed. Age, sex, education, hearing loss severity, and cognitive impairment were found to be significantly related to DDT scores but explained less than 25% of the total variability in total free recall scores. The right ear directed recall DDT by itself may not be of benefit in assessing central auditory processing in a general population because of its limited variability but further evaluation of factors potentially related to free recall DDT variability may prove useful.

INTRODUCTION

Measurement of central auditory processing (CAP) has taken on new importance for research purposes since a number of investigations in recent years have found a relationship between central auditory dysfunction and cognitive disorders, including Alzheimer's disease (AD), mild cognitive impairment, memory impairment without dementia, and cognitive decline (Hällgren et al. 2001; Gates et al. 2002, 2008, 2010, 2011; Idrizbegovic et al. 2013). For example, in the Framingham Heart Study cohort, very poor performance in either ear on the Synthetic Sentence Identification with Ipsilateral Competing Message (SSI-ICM) test was significantly related to the risk of developing AD over a follow-up period of up to 16 years (Gates et al. 2002). In a longitudinal study using the Dichotic Digits Test (DDT) with double-digit pairs, there was a significant difference in decline on the test between a small group of subjects with AD and subjects with memory complaints but no impairment (Idrizbegovic et al. 2013). This difference was observed in as little as 1.5 years of follow-up and was limited to the more challenging conditions of free recall in the left ear (non-dominant).

Dichotic speech listening tests have been used to measure CAP performance. Dichotic tests challenge the auditory system and cognitive functioning, with tasks like attention focusing and use of working memory. The DDT, in which single-syllable numbers are presented simultaneously in each ear, usually in double-digit or triple-digit pairs, is one such test that has been used to evaluate CAP (Musiek et al. 1991; Gates et al. 2008, 2010, 2011). Among the strengths of the test are its ease of use, short administration time, and fairly good test-retest reliability (Strouse & Wilson 1999), even in the presence of Alzheimer's disease (Strouse & Hall 1995). Little work has been done describing the performance of the DDT in the general population. Strouse and Wilson (1999) developed normative data for both the free (subjects repeat digits presented in both ears) and directed recall (subjects repeat digits presented in one specified ear) DDT based on findings in 180 individuals (age range 20-79 yrs) recruited from the community or from audiology clinics. In addition, the one-, two-, and three-digit pair modalities were randomly presented in both the free recall and the directed recall testing. Results showed that for double- and triple-digit pairs, randomly presented, mean free recall scores were generally lower than mean directed recall scores and age was significantly associated with performance, whereby persons of older ages performed poorer than persons of younger ages, particularly in the free recall condition (Strouse & Wilson 1999). The age effect remained after adjustment for differences in the audiometric thresholds between the age groups. Stimuli had been presented at 70 dB HL. The largest test-retest differences in the age group mean scores was less than 1 digit for directed recall and approximately 2 digits for free recall of the triple-digit pairs in the oldest age group (70-79 yrs).

A number of studies have demonstrated a similar inverse relationship between age and dichotic listening tests, including tests using digits, words, and sentences (Jerger et al. 1994; Wilson & Jaffe 1996; Strouse et al. 2000; Hällgren et al. 2001; Gates et al. 2002, 2011; Roup et al. 2006). In addition, in a study evaluating the relationship between CAP and cognitive disorders, education was also found to be related to CAP performance whereby subjects with more education performed better on the Dichotic Sentence Identification test (worse ear) (Gates et al. 2011).

Many of the previous dichotic listening studies have only included small groups of clinic-based subjects (Jerger et al. 1994; Wilson & Jaffe 1996; Strouse et al. 2000; Hällgren et al. 2001; Roup et al. 2006) and have adjusted for potential confounding of the CAP test performance and covariate relationships by audibility level in a variety of ways. For example, in one study adjustment for hearing thresholds was done by allowing the participant to adjust the initial presentation level of 73 dB SL to a preferred level (Hällgren et al. 2001). In another study, in addition to changing the presentation to an adequate and comfortable level, a sensitivity analysis was conducted by selecting a sub-sample of subjects with similar average audiometric thresholds (Jerger et al. 1994). Adjustment for pure-tone threshold averages in statistical modeling has also been performed (Gates et al. 2002).

The objective of the present study was to describe the distribution of the DDT free and right ear directed recall performance in a large cohort drawn from a general population spanning a wide age range. The relationship between DDT performance and the demographic factors of age, sex, and education was assessed. The association of hearing loss severity and cognitive impairment with DDT scores was also evaluated.

METHODS

Study Population

Participants were members of the Epidemiology of Hearing Loss Study (EHLS) or the Beaver Dam Offspring Study (BOSS). The EHLS and the BOSS are prospective cohort studies of aging. Individuals who had participated in the baseline Beaver Dam Eye Study (BDES) in 1987-1988 were eligible to participate in the population-based EHLS and the baseline EHLS examination took place concurrently with the first BDES follow-up in 1993-1995. There were 3753 EHLS participants at baseline with an age range of 48 to 92 yrs. Follow-up examinations have been conducted at 5 year intervals with greater than 80% participation rates and the data in the current study are from the 4th EHLS examination (2008-2010). In-office audiometric testing was administered to 1549 participants and of these, 1391 completed the free recall and right ear directed recall DDT. There were 158 participants who were not offered or did not complete the DDT because of hearing severity or asymmetry (n = 103), not successfully completing the DDT training (n = 13), the participant requesting to stop (n = 14), or other/unknown reasons (n = 28). Details of the EHLS and BDES may be found in previous reports (Klein et al. 1991; Cruickshanks et al. 1998, 2003).

The adult children of the EHLS participants were eligible for BOSS and 3296 offspring (age range of 21 to 84 yrs) participated during the baseline BOSS phase, conducted in 2005-2008 (Nash et al. 2011). The 5 year follow-up (BOSS-2) was conducted in 2010-2013 with a greater than 80% participation rate. Information from 2264 participants examined in BOSS-2 is used in the current study. There were an additional 82 participants without complete DDT data because of hearing severity or asymmetry (n=28), failing to complete the training (n=11), participant requesting to stop (n = 26), or other/unknown reasons (n = 17). Additional information regarding the BOSS cohort has been reported (Zhan et al. 2010; Nash et al. 2011).

Approval for this research was obtained from the Health Sciences Institutional Review Board of the University of Wisconsin and informed consent was obtained from all participants prior to each examination.

Measurements

Pure-tone Audiometric Testing—Audiometric testing was conducted in the EHLS and BOSS by trained and certified examiners and followed the American Speech-Language-Hearing Association guidelines in compliance with the American National Standards Institute standards (American Speech-Language-Hearing Association 1978; American National Standards Institute 1999; American National Standards Institute 2010). In-office testing was done using clinical audiometers with TDH-50P earphones and ER-3A insert earphones (in cases of probable ear canal collapse) in sound-treated booths. Pure-tone air-conduction thresholds were obtained for both ears at 0.5, 1, 2, 3, 4, 6, and 8 kHz, and bone-conduction thresholds were obtained at 0.5, 2, and 4 kHz. Masking was done when necessary (Cruickshanks et al. 1998, 2003). The pure-tone average (PTA) at 0.5, 1, 2, and 4 kHz in the worse ear was calculated and used to categorize hearing loss severity according to the following definitions: No Loss = PTA ≤25 dB HL; Mild Loss = 25 < PTA ≤40 dB HL; Moderate or Marked Loss = PTA >40 dB HL.

Dichotic Digits Tests—The free and right ear directed recall DDTs were administered with 25 sets of triple-digit pairs (3 digits presented to each ear simultaneously), with single-syllable numbers 1 through 10 (excludes 7). The free recall task required the participant to repeat as many of the 6 digits as possible; the right ear directed recall task required repeating only the 3 digits presented to the right ear. The presentation level was set at 70 dB HL. Directed recall left ear was not performed because of time considerations. For training and practice, prior to testing, 3 examples each of single-digit pairs, double-digit pairs, and triple-digit pairs were presented. If the participant was unable to repeat any of the numbers in the single-digit or double-digit pairs examples or did not attempt to repeat any of the numbers in the triple-digit pairs example, the DDTs were not administered. The free recall DDT was performed first, followed by the right ear directed recall DDT. The sum of the right and left ear scores was used as the measure of function on the free recall DDT. Therefore, the possible range of the correct number of repeated digits was 0 to 150 (75 digits per ear) for the total free recall and 0 to 75 for the right ear directed recall. For analysis and presentation purposes, the correct number was converted to the percent correct.

Cognitive Impairment—The Mini-Mental State Examination (MMSE) test (Folstein et al. 1975) was examiner-administered to participants aged 50 years and older following the same standardized protocol in both the EHLS and the BOSS. Cognitive impairment was considered present if the MMSE score was less than 24 (out of a maximum of 30) or if there was a self- or proxy-reported history of dementia or AD (Schubert et al. 2008). Participants under the age of 50 years were assumed to have no cognitive impairment. For a secondary analysis, participants were grouped according to the MMSE score into 3 categories: < 24, 24-27, and 28-30. Participants under age 50 were placed in the 28-30 category.

Covariates—Demographic factors included in the analyses were age, sex, and education. Education was categorized as less than high school graduate (<12 years), high school graduate (12 years), some college (13-15 years), and college graduate or beyond (16+ years). Handedness was determined through the question, “Are you right or left handed?” with possible responses of “Left”, “Right”, “Use both equally”, and “Unknown”.

Statistical Methods

All analyses were completed using the SAS version 9.4 software (SAS Institute, Inc. Cary, NC).

PROC GLM was used to perform general linear modeling to test for an association of age, sex, education, hearing loss severity and cognitive impairment with free recall and right ear directed recall performance and to estimate age-sex adjusted least squares means. The ObsMargins (OM) adjustment was applied to allow for estimates proportional to the margins observed in our population. Multivariable modeling was performed using multiple linear regression with the total free recall DDT score as the dependent variable and the covariates as the independent variables. Indicator variables were used for the categorical covariates. The R-squared from the regression model provided the percent of total variability in free recall scores explained by the included independent variables. A test for a linear trend in the association between MMSE category and free recall DDT score was performed by entering the MMSE category number as an ordinal variable in the modeling. Linear regression was not performed with the right ear directed recall scores because of the skewness of the distribution and the very limited variability.

RESULTS

The average age of the 3655 subjects included in the study was 61.1 yrs (range = 21-100 yrs) and 43.8% were male. Overall the mean free recall score was 76.7% correct and the mean right ear directed recall score was 98.4%. Total free recall scores ranged from 21.3% to 100% (Fig. 1a – Distribution of Free Recall Dichotic Digits Score). Approximately two-thirds of the participants had total free recall scores between 65% and 89% correct and another 16% had a score of at least 90% correct or better. Less than 10% of the participants had a free recall score below 60% correct. The majority of participants performed better in the right ear than the left ear in the free recall DDT (see Table, Supplemental Digital Content 1, which displays the distribution of the right ear performance by left ear performance in the free recall DDT).

For the right ear directed recall test scores, 69% of the participants had 100% correct and 15.5% only had 1 incorrect digit (Fig. 1b – Distribution of Directed Recall Dichotic Digits Score). Therefore, only 15% of the participants missed 2 or more digits (<99% correct).

Age, sex, and education were significantly ($p < 0.0001$) associated with total free recall performance (Table 1). Older ages demonstrated lower mean free recall scores; for example, those aged 80 yrs or older had a sex-adjusted mean score of 67.1% compared with 82.5% for participants less than 40 yrs of age. Males had a significantly lower mean age-adjusted free recall score (74.9%) than females (78.0%) and the gradual decrease in free recall scores across age groups was observed in both males and females (Fig. 2) with the decrease beginning at an earlier age for males. There was a direct relationship between education and free recall performance so that as the number of years education increased, mean age-sex adjusted scores increased. Similar significant relationships were observed for age and education with right ear directed recall performance but, in contrast to the free recall results, there was almost no difference between males and females in the age-adjusted mean right ear directed recall scores.

Hearing loss severity was also significantly ($p < 0.0001$) related to total free recall and right ear directed recall scores (Table 1) so that groups with more severe hearing loss had poorer mean DDT performance. Finally, the age-sex adjusted mean DDT score in participants with cognitive impairment was 11.5 percentage points lower for free recall and 8.9 percentage points lower for right ear directed recall than in participants without cognitive impairment ($p < 0.0001$).

In multiple linear regression modeling of the total free recall scores, age, sex, education, hearing loss severity, and cognitive impairment were all independently and significantly related to performance (Table 2). The predicted mean free recall score decreased by 1 percentage point for every 5 year increase in age, males had a mean predicted score 2.3 percentage points lower than females, participants with less than a high school degree had an adjusted mean free recall score 8.7 percentage points lower than those with college degrees and the average adjusted score of those with a moderate or marked loss was 6.8 percentage points lower than participants with no hearing loss. Finally, participants with cognitive impairment had an adjusted mean free recall score 8.3 percentage points lower than participants without cognitive impairment. The 5 factors included in the multivariable model accounted for 22.7% of the total variability in free recall scores. In a model with the categorized MMSE score in place of cognitive impairment, a significant ($p < 0.0001$) linear trend was observed whereby participants with an MMSE score less than 24 and those with an MMSE score of 24 to 27 had adjusted mean free recall scores 9.4 percentage points and 3.4 percentage points, respectively, lower than participants with an MMSE score of 28 to 30 (data not shown).

Models evaluating the factors related to the difference between the right and left ear performance demonstrated that age, education, and cognitive impairment were significantly associated with the difference (see Table, Supplemental Digital Content 2, which describes the results of multivariable linear regression with right minus left ear difference as outcome). Participants who were older, had less education or were cognitively impaired had greater predicted mean right minus left ear differences. There was no significant association between the right-left ear difference and sex or severity of hearing loss. When handedness was added to the model, there was very little change in the results for age, sex, education, hearing loss severity, and cognitive impairment (data not shown). Participants who were left-handed had an adjusted mean right-left ear difference that was 5.1 percentage points less than right-handed participants.

DISCUSSION

The present report includes information on the distribution of DDT free and right ear directed recall scores using triple-digit pairs in a large study population spanning a wide age range. Results showed extensive variability in free recall performance and evidence of a right ear advantage in the majority of participants. Very limited variability in right ear directed recall scores was observed with the majority of participants achieving a perfect score on the right ear directed recall test. The free recall DDT involved participants attempting to repeat all digits presented in both ears. This type of task has been termed a binaural integration task (Musiek & Pinheiro 1985). The right ear directed recall DDT involved digits being presented in both ears but the participants being instructed to repeat only the digits presented in the right ear. This type of task has been termed a binaural separation task (Musiek & Pinheiro 1985). The right ear directed recall test was less challenging than the free recall test and therefore, it is not surprising that performance was considerably better on the right ear directed DDT compared with the free DDT.

Age, sex, education, hearing loss severity, and cognitive impairment were found to be significantly related to DDT scores although these 5 factors explained a relatively small degree of the total variability in the total free recall scores. Older ages demonstrated lower average scores than younger ages. Age group-specific mean scores of the total free recall DDT in the current study were compatible with the observed ear-specific triple-digit pair age group mean scores cited in the Strouse and Wilson normative work whereas directed recall DDT mean scores by age group were slightly higher in the present study (Strouse & Wilson 1999). This difference is not surprising given that in the Strouse and Wilson work, the directed recall testing was performed for both the right and left ears (with pre-cueing of the test ear preceding the presentation of the digits) rather than only the right ear. In addition, the one-, two-, and three-digit pair modalities were randomly presented in both the free recall and the directed recall testing. These differences in methodology provide a more challenging test than in the present study. The observed inverse relationship between age and DDT performance has been reported previously in smaller studies of dichotic listening measures in selected study populations (Wilson & Jaffe 1996; Strouse et al. 2000; Hällgren et al. 2001) although not all studies found an age-DDT association (Humes et al. 1996). The association of age with DDT performance was of greater magnitude under the free condition than the right ear directed condition in the present study most likely as a result of the limited variability in the right ear directed recall scores but possibly also as a result of the higher challenge involved in the free recall test compared with the right ear directed recall test. There have been reports suggesting that the strength of the inverse age and DDT performance relationship was dependent on the complexity of the task with the more complex tasks displaying stronger age associations (Wilson & Jaffe 1996; Strouse et al. 2000).

Previous studies have not specifically investigated the association of sex and education with the DDT but a report from the Blue Mountains Hearing Study did indicate that males were significantly more likely than females to exhibit poor performance on CAP tests but the difference was confined to dichotic listening tests (right ear, left ear, and right-left ear difference) (Golding et al. 2006). It was hypothesized that it may be related to sex differences in the rate of corpus callosum degeneration (Golding et al. 2006). It is important to note that in the present study, the lower average total free recall scores observed in males compared with females remained after adjustment for hearing loss severity.

Although hearing loss severity was classified using only the thresholds measured at 0.5, 1, 2, and 4 kHz, the stimuli presented in the DDT are primarily in the low or mid-frequency range. In addition, the majority (64%) of those with a hearing loss had a mild loss. Therefore, the 70 dB HL presentation level very likely ensured audibility. The inverse relationship between hearing loss severity and free recall DDT performance may be a reflection of residual confounding. Adjustment was made for age, sex, education, and cognitive impairment but additional confounders may exist. Alternatively, the observed relationship may indicate that there is a link between performance on the pure-tone audiometric testing and the dichotic listening test beyond audibility (common cause for poor performance). Pure-tone audiometric testing is not strictly a test of peripheral hearing; it requires cognitive functioning for listening, attention, interpretation of signals and formation of a response. These findings suggest that future work should not only control for audibility by presenting stimuli at 70 dB HL, but should also consider adjusting for hearing sensitivity through selection of a restricted level of hearing loss or through statistical adjustment for sensation level.

A relationship between poor performance on dichotic listening tests and cognitive decline and impairment, both cross-sectionally and prospectively, has been reported (Hällgren et al. 2001; Gates et al. 2002, 2008, 2010, 2011; Idrizbegovic et al. 2013). The present study evaluated cognitive impairment based on the MMSE score and found a similar cross-sectional relationship which continued to be significant in the multivariable model. It has been observed that CAP test performance, particularly when competing signals are present, is associated with performance on executive function tests (Gates et al. 2010). Executive function tasks such as short-term memory and attention are involved in the dichotic listening environment and it was suggested that decline in central auditory and executive functioning may share a common cause, likely related to neurodegeneration (Gates et al. 2010). The link between executive functioning and dichotic listening test performance could also mean that individuals with greater levels of cognitive reserve or function may continue to perform well on the CAP tests even with degraded or distorted auditory input (Humes et al. 2012). This suggestion may help explain the direct relationship between DDT performance and education level observed in the present study.

Among this study's strengths are the large size of the study population and the wide age range. The DDT was administered by trained and certified examiners following a standard protocol. The DDT has been shown to have good test-retest reliability in the Strouse and Wilson work in which one-, two-, and three-digit pair modalities were randomly presented (Strouse & Wilson 1999). Audiometric testing and the administration of the MMSE, used to define cognitive impairment, were also conducted by trained and certified examiners. Finally, information on educational attainment was available. Limitations included the cross-sectional design of the study which prevented drawing any conclusions regarding longitudinal associations. Only cognitive impairment based on the MMSE was evaluated and not performance on specific cognitive tests or cognitive decline over time.

The present study found substantial variation in the total free recall DDT scores in a study population of approximately 3600 subjects with an age range of 80 years. Very little variation was observed in the right ear directed recall test scores which suggests that the right ear directed test, either by itself or in conjunction with the free recall test, has limited usefulness in assessing or differentiating CAP performance in a general population. Age, sex, education, hearing loss severity, and cognitive impairment were found to be significantly related to DDT scores but explained less than 25% of the total variability in the total free recall scores. Therefore, additional research may be of benefit to determine other factors which are contributing to the remaining variation in the DDT scores.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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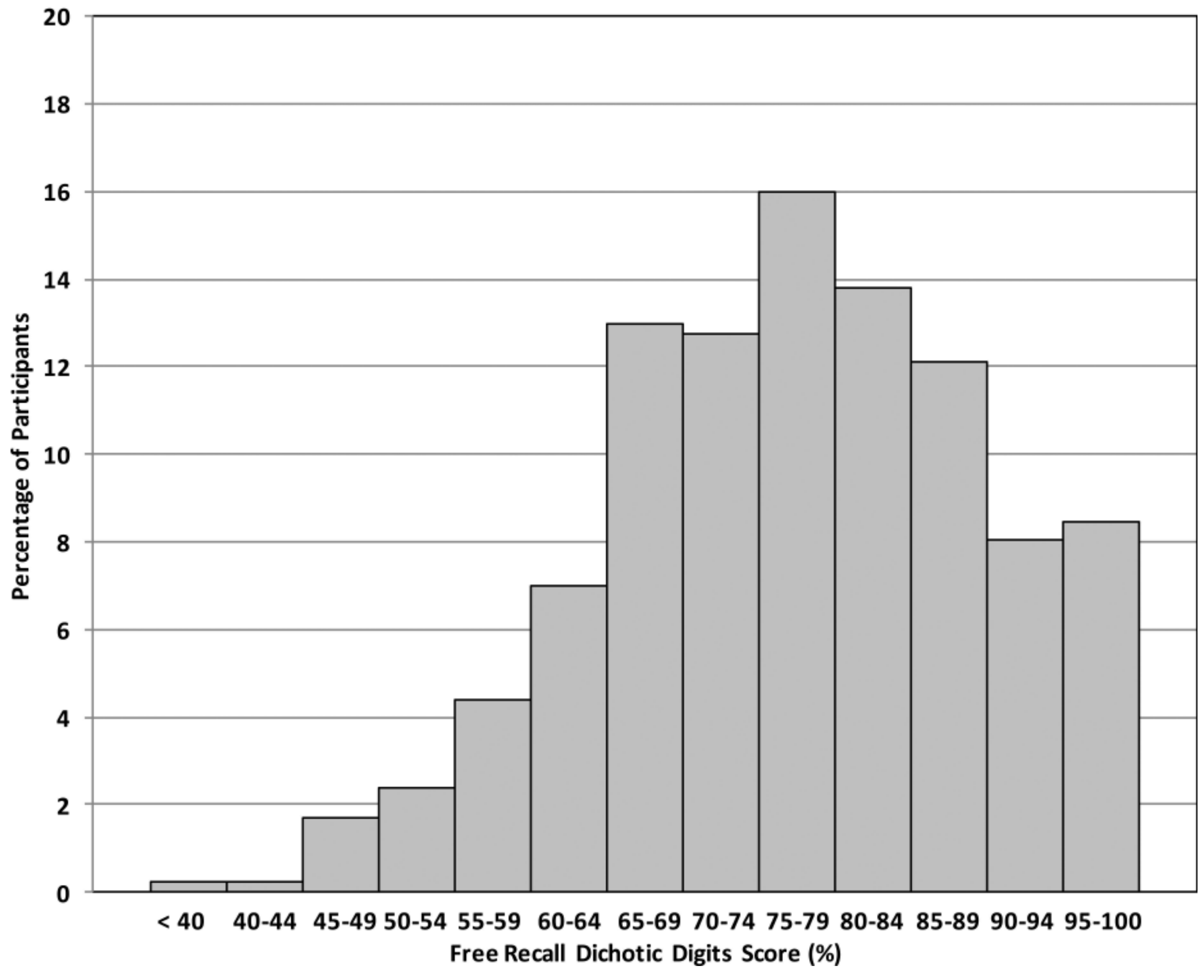

Percentage of Participants
0
2
4
6
8
10
12
14
16
18
20
< 40
40-44
45-49
50-54
55-59
60-64
65-69
70-74
75-79
80-84
85-89
90-94
95-100
Free Recall Dichotic Digits Score (%)

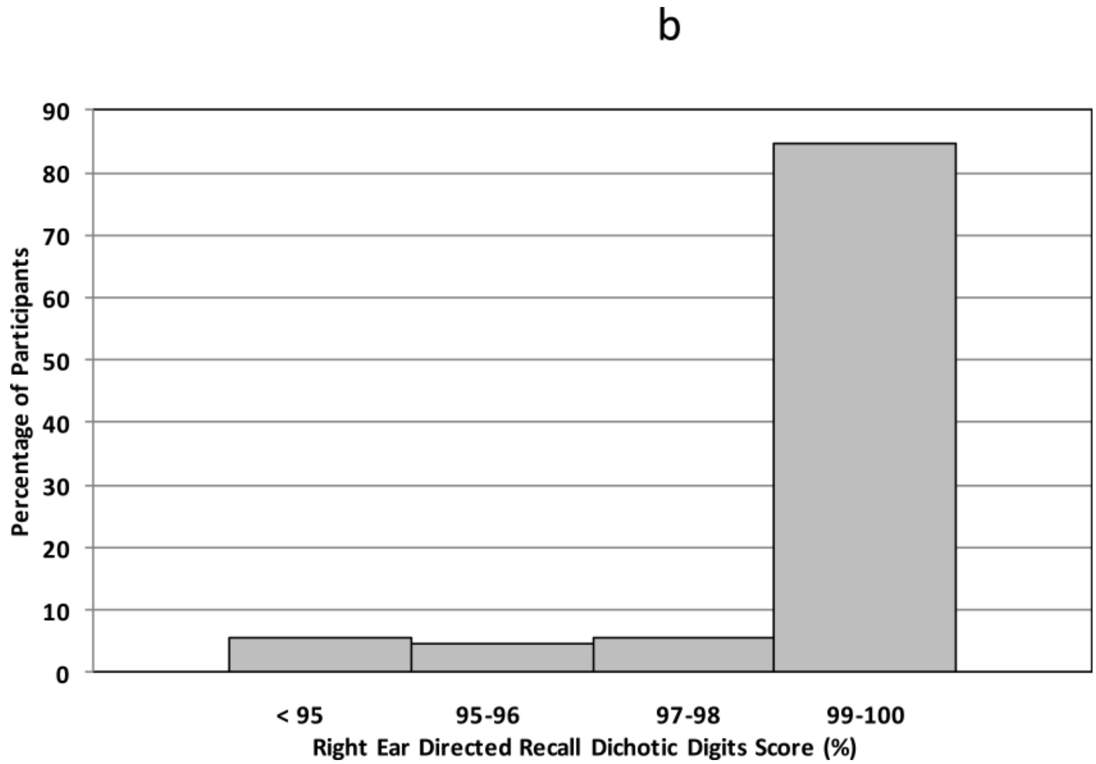

Fig. 1.

A, Distribution of free recall dichotic digits score (%). B, Distribution of right ear directed recall dichotic digits score (%).

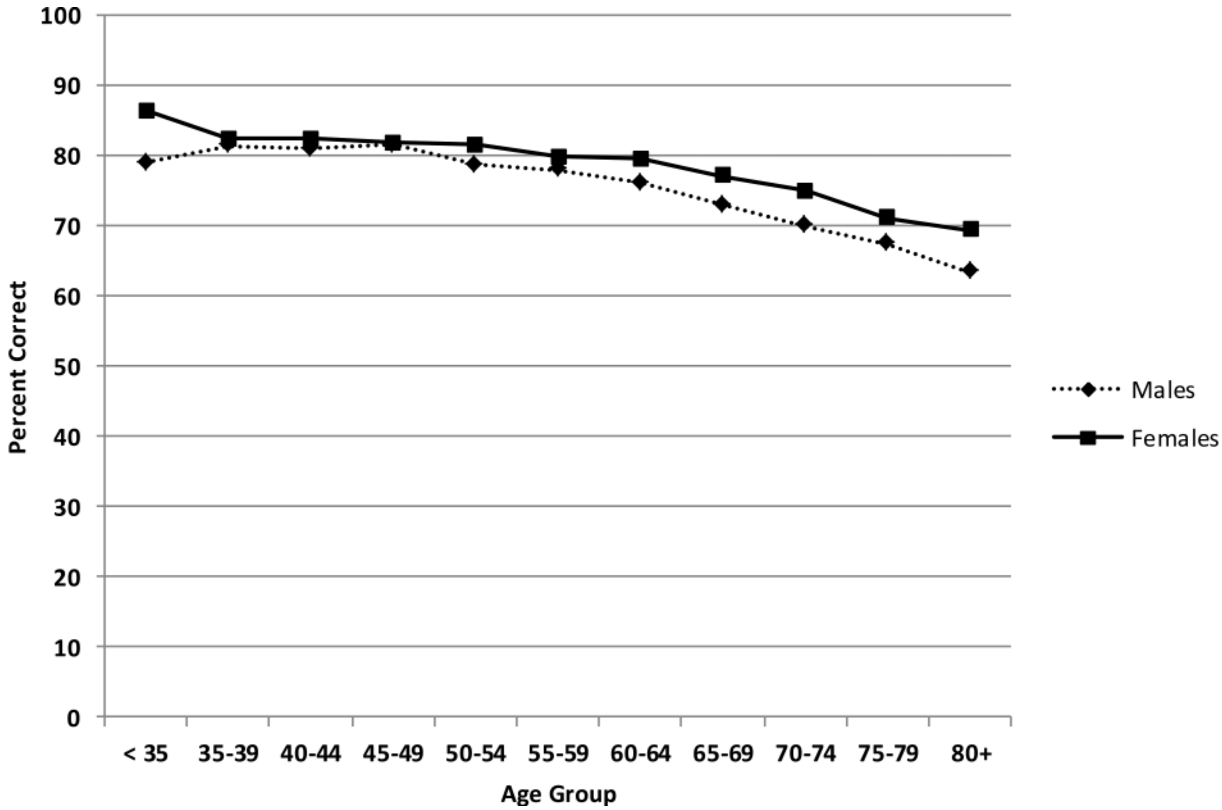

Fig. 2.
Mean free recall dichotic digits test score (%) by age group and sex.

Table 1

Free and Right Ear Directed Recall Dichotic Digits Test Score (%) Adjusted Means by Participant Characteristics

		Free Recall		Right Ear Directed Recall	
	N	**Mean**	**p-value**[†]	**Mean**	**p-value**[†]
Overall	3655	76.7		98.4	
Age Group[*]			< 0.0001		< 0.0001
21-39	145	82.5		99.3	
40-59	1552	80.6		99.2	
60-79	1632	74.3		98.4	
80+	326	67.1		94.7	
Sex[**]			< 0.0001		0.25
Male	1600	74.9		98.3	
Female	2055	78.0		98.5	
Education[‡§]			< 0.0001		< 0.0001
< High School Graduate (<12 years)	204	69.0		95.9	
High School Graduate (12 years)	1328	74.8		98.5	
Some College (13-15 years)	1027	77.3		98.5	
College Graduate (16+ years)	1091	79.7		98.8	
Hearing Loss Severity[‡]			< 0.0001		< 0.0001
No Loss (PTA ≤25 dB HL)	2412	78.2		99.0	
Mild Loss (25 < PTA ≤40 dB HL)	799	75.8		98.6	
Moderate/Marked Loss (PTA >40 dB HL)	444	70.2		95.2	
Cognitive Impairment[‡¶]					
Yes	62	65.4	< 0.0001	89.7	< 0.0001
No	3583	76.9		98.6	

[†] p-value refers to the significance of the specified characteristic's overall effect after age and sex adjustment

[*] Sex-adjusted

[**] Age-adjusted

[‡] Age- and sex-adjusted

[§] 5 missing education information

[¶] 10 missing cognitive impairment information

Table 2

Free Recall Dichotic Digits Test Score (%) Multivariable Linear Regression Model*

	Free Recall Dichotic Digits Test Score (%)		
	B **(%)**†	**Standard Error**	**p-value**
Age (5 yr)	−1.01	0.08	< 0.0001
Sex			
Female	Ref	-	-
Male	−2.29	0.38	< 0.0001
Education			
< High School Graduate (<12 years)	−8.74	0.88	< 0.0001
High School Graduate (12 years)	−4.54	0.46	< 0.0001
Some College (13-15 years)	−2.26	0.48	< 0.0001
College Graduate (16+ years)	Ref	-	-
Hearing Loss Severity			
No Loss (PTA ≤25 dB HL)	Ref	-	-
Mild Loss (25 < PTA ≤40 dB HL)	−2.13	0.50	< 0.0001
Moderate/Marked Loss (PTA >40 dB HL)	−6.78	0.65	< 0.0001
Cognitive Impairment			
No	Ref	-	-
Yes	−8.32	1.44	< 0.0001

*15 missing complete information and not included in the model

†*B* = regression coefficient indicating predicted adjusted mean score (%) difference between specified covariate level and reference level