Neuropsychological Data in Non-Demented Oldest-Old:

The 90+ Study

Christina Whittle[1], María M. Corrada[1,2], Malcolm Dick[1], Raphael Ziegler[1], Kristin Kahle-Wrobleski[1] , Annlia Paganini-Hill[3], Claudia Kawas[1,2,4]

1 Institute for Brain Aging and Dementia, University of California, Irvine, CA, USA

2 Department of Neurology, University of California, Irvine, CA, USA

3 Department of Preventive Medicine, Keck School of Medicine, University of Southern California, Los Angeles, CA, USA

4 Department of Neurobiology & Behavior, University of California, Irvine, CA, USA

Corresponding Author:

Claudia Kawas

1121 Gillespie, Irvine, CA 92697-4540

Phone: 949-824-2323; FAX: 949-824-4165

Email: ckawas@uci.edu

Acknowledgements

The 90+ Study is supported by the National Institute on Aging grant R01AG21055 and the Al and Trish Nichols Chair in Clinical Neuroscience. The authors thank the extraordinary participants and families of the 90+ Study who made this work possible. We also acknowledge the great work of all the psychometric testers, neurological examiners, and study staff.

ABSTRACT

Although the oldest-old are the fastest growing segment of the population, little is known about their cognitive performance. Our aim was to compile a relatively brief test battery that could be completed by a majority of individuals aged 90 or over, compensates for sensory losses, and incorporates previously validated, standardized and accessible instruments. Means, standard deviations, and percentiles for ten neuropsychological tests covering multiple cognitive domains are reported for 339 non-demented members of the 90+ Study. Cognitive performance declined with age for two-thirds of the tests. Performance on some tests was also affected by gender, education, and depression scores.

Keywords

Nonagenarians, Test Norms, Cognitive Ability, Neuropsychology, Age Differences, Educational Attainment

INTRODUCTION

Individuals over the age of 90 represent one of the fastest growing segments of the United States population. According to the US Census, approximately 1.5 million individuals were aged 90 and older in 2000 (U.S. Census Bureau, 2001). Within the elderly population, the number of individuals aged 90 and older showed the largest increase (45%) between 1990 and 2000 and is expected to increase to over 10 million people by 2050. Despite these changing demographics and the increasing numbers of older adults referred for neuropsychological evaluation, little normative data is available to clinicians who evaluate the oldest old.

Neuropsychological assessment has retained its key role in the diagnosis of AD and other forms of dementia despite improvements in neuroimaging techniques such as magnetic resonance imaging (MRI) and photon emission tomography (PET). According to criteria from the National Institute of Neurological and Communicative Disorders and Stroke-Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA), a clinical diagnosis of possible or probable AD can be based on an individual's neuropsychological test profile after all other possible medical, psychiatric, and neurological explanations for the symptoms have been excluded (McKhann et al., 1984). The NINCDS-ADRDA guidelines established neuropsychological criteria, with the cutoff score for impairment as being the 5^{th} percentile or lower in eight cognitive domains including orientation, memory, attention, language, perceptual skills, praxis, reasoning, and functional status. Since memory and other cognitive impairments are the primary and most important criteria for the diagnosis of dementia, and given the increasing prevalence of dementia with advancing age, it is essential that clinicians have reliable and valid neuropsychological tests with appropriate norms in order to successfully differentiate elderly individuals with cognitive deficits from those who remain mentally intact. Consequently, the purpose of the present study was to develop a battery of neuropsychological instruments appropriate for assessing the cognitive functioning of the oldest old, and to collect sufficient normative data to allow clinicians to differentiate healthy from impaired elderly in this advanced age group.

During the past 40 years, clinicians and researchers have developed numerous instruments (e.g. Halstead-Reitan Neuropsychological Battery (Reitan, 1985), Wechsler Adult Intelligence Scale (Wechsler, 1981), Wechsler Memory Scale (Wechsler, 1997b)) for the purpose of assessing changes in an individual's cognitive status. Due to long administration time, many of these instruments have proved too taxing for elderly individuals who are more susceptible to fatigue (Putnam, 1990), frustration, and uncooperativeness (Lichtenberg, 2003). Thus, it is difficult for clinicians and researchers to draw valid conclusions regarding individuals' actual cognitive abilities. In an effort to decrease administration time and maintain rapport with the patient, clinicians have frequently relied on shorter screening measures such as the Mini-Mental State Examination (MMSE) (Folstein et al., 1975). While brief, screening instruments lack sensitivity for detecting subtle or mild forms of cognitive impairment (Petersen et al., 1994).

Recently, researchers have started to address issues such as testing fatigue by developing batteries of reasonable length and administration time, such as the Consortium to Establish a Registry for Alzheimer's Disease (CERAD) (Morris et al., 1989) and the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS) (Randolph, 1998). While scores on the CERAD and RBANS batteries can help differentiate healthy from cognitively impaired individuals, neither battery provide adequate normative data for persons over the age of 89. Additionally, one of the most frequently used normative data sets for older individuals is the "Neuropsychological Tests Norms Above Age 55" (Ivnik, 1996). These norms, derived from the

Mayo's Older Americans Normative Studies (MOANS), have made a significant contribution to the literature, but ages were aggregated so that individuals as young as 76 years of age were included in the oldest age category. Indeed, a review of the neuropsychological literature yielded relatively few studies with adequate sample sizes to allow clinicians to draw any clear conclusions regarding test performance in individuals aged 90 and older.

Consequently, the need for a standardized neuropsychological battery with norms appropriate for use with the oldest old is paramount. To address this limitation, we compiled a battery of ten tests assessing seven domains including global cognition, language, recent memory, executive function, psychomotor speed, visual-spatial ability, and attention / working memory. Our aim was to compile a battery of tests that would (1) discriminate between cognitive changes associated with normal aging and those seen in dementia, (2) be relatively brief and easily completed by a majority of individuals over the age of 90, (3) compensate for sensory losses (hearing and vision deficits) often present in the oldest old, and (4) incorporate previously validated, standardized and accessible instruments already familiar to many clinicians and researchers.

In this study, we report normative data on the Mini-Mental State Examination (MMSE), the Modified Mini-Mental (3MS; Teng & Chui, 1987), 15-item Boston Naming Test (BNT; Kaplan et al., 1978; Mack et al., 1992), Letter and Category Verbal Fluency (Benton & Hamsher, 1989; Morris et al., 1988), California Verbal Learning Test-II Short Form (CVLT-II, Short Form; Delis, 1987; Delis et al., 2000), Trail Making Test A, B, and C (TMT A, B, & C; Army Individual Test Battery, 1944; Delis, 2001), Clock Drawing Test (Freedman et al., 1994; Rouleau et al., 1992), CERAD Constructions (Morris et al., 1988), and WAIS-III Digit Span (Wechsler, 1997a).

METHODS

The 90+ Study Sample

The 90+ Study is a longitudinal, population-based investigation of aging and dementia in the oldest-old. In the early 1980s, a health survey was mailed to residents of Leisure World, a retirement community in southern California. The 13,978 residents who completed the survey became members of the Leisure World Cohort Study (Paganini-Hill A, 1989; Paganini-Hill A, 1986). These participants are followed by periodic resurvey (1983, 1985, 1992, and 1998) and determination of vital status by search of national and commercial death indices and ascertainment of death certificates. The 1,150 individuals still alive and aged 90 years or older on January 1, 2003 were eligible for participation in The 90+ Study. All participants were asked to undergo a comprehensive in-person evaluation or to provide information via self-completed or informant-completed mailed questionnaires. The in-person evaluation included past medical history, family history, functional assessments, neurological examination, and neuropsychological battery. The subjects of this study comprise the first 339 non-demented participants of the initial 481 participants who were examined in-person as of October 2004. All participants provided written informed consent and all procedures performed were approved by the Institutional Review Board of the University of California, Irvine.

Neuropsychological Battery

A neuropsychological test battery that could assess multiple domains in a large population of 90+ year olds of various abilities, without excessive floor or ceiling scores, was desired. Several memory tests, including CERAD word list (Morris et al., 1988), Cued Selective Reminding (Grober & Buschke, 1987), New York University Paragraph Recall (Kluger, 1999), and Logical

Memory (Wechsler, 1997a, 1997b), were piloted and rejected due to either floor scores, length of administration, or both. The resulting battery included ten tests assessing multiple cognitive domains. Tests were administered in the order shown in Table 1 with standardized administration by trained and certified psychometrists. Amplifiers were provided for participants who were extremely hard of hearing, and visual stimuli were presented in size 90 boldface font to promote visibility. The average time to complete the entire battery was one hour. The Geriatric Depression Scale (GDS) (Yesavage, 1982) was included to explore the relation between affective state and cognition and was administered after the test battery. A brief description of the individual tests in the battery and any modifications made in the administration procedures follow.

Global Cognition

The participant's overall cognitive functioning was evaluated with the Modified Mini-Mental State Examination (3MS) which tests ten cognitive domains: attention, concentration, orientation, short-term memory, long-term memory, verbal fluency, reading, writing, constructional praxis, and abstraction. As all of the items from the MMSE are incorporated in the 3MS, a MMSE score can be easily derived for each individual. Total scores on the 3MS range from 0 to 100 points while scores on the MMSE range from 0 to 30 points. The only change made to the standard administration procedure was that the three to-be-remembered words were printed on separate cards using enlarged font and presented to the participant at the same time as the examiner said the words aloud.

Language

Three tests were used to assess language abilities, namely confrontational object naming, category fluency for animal names, and letter fluency (F). A short, 15-item version of the BNT was used rather than one of the longer 30-, 45-, or 60-item versions to minimize fatigue. The Animal Fluency test requires the participant to name aloud as many animals as he/she could in one minute. This test is performed as part of the 3MS. Participants received credit for naming general categories as well as specific exemplars, but not for both. For example, if the examinee gave an exemplar (*e.g.,* eagle) from an already named category (*e.g.,* bird), credit was only given for the exemplar. Extinct animals (*e.g.,* dinosaur) were credited, but not mythical creatures (*e.g.,* unicorn). Repeated responses were counted only once. Letter fluency was assessed using only letter "F" rather than the more traditional three letters (F, A, S) to reduce administration time and fatigue. On this test, the participant was asked to name aloud in one minute as many words starting with the letter 'F' as he/she could. To avoid confusion with similar sounding letters, a large F was printed in 200-size font on a card and presented as a prompt during this test. Points were not awarded for responses that included proper nouns or variations on the same word (e.g. fall, falling).

Recent Memory

Recent memory was assessed with a modification of the short 9-item version of the CVLT-II. In this test, the participant is asked to remember a list of 9 words across four learning trials. The list is comprised of three words from three different categories presented in a random order. The same order of stimulus presentation is used across the four trials and each learning trial is followed by a test of immediate free recall. Our primary modification was to present the words both verbally and visually during the four learning trials, rather than only saying the words aloud as recommended in the standard instructions. A Short-Delay Free Recall test was administered following an interference task of counting backwards from 100 by ones for 30 seconds. After approximately 10 minutes of nonverbal testing, the Long-Delay Free Recall was administered and was immediately followed by tests of cued-recall and yes/no recognition.

Executive Function

Parts A and B of the TMT were administered with standard procedures. TMT A requires the participant to connect the dots in numerical order, 1-2-3 and so on. TMT B requires the participant to connect the dots in order by shifting set, 1-A-2-B-3-C and so on. The maximum time limits for Parts A and B were extended to 180 and 300 seconds, respectively.

Psychomotor Speed

On Part C of the TMT, the participant uses a colored marker to trace a dotted line connecting 25 circles. The original Delis-Kaplan Executive Functioning version of the TMT Part C is a two-page task, which our participants found daunting. Therefore we proportionately modified the two-page version into a comparable one-page version, which was better received by participants. The amount of time the participant needed to trace over the dotted line from the ‘start’ to ‘finish’ circles was recorded in seconds.

Visual-Spatial Abilities

In the Clock Drawing Test the participant was asked to place the numbers as on a clock on a pre-drawn circle and draw the minute and hour hands to show “ten after eleven.” Scoring was based on the presence and sequencing of the numbers and the positioning of the two hands. The CERAD Figure Drawing Test asked the participant to copy four line drawings of increasing complexity (*i.e.,* circle, four-sided diamond, intersecting rectangles, and cube). Standard scoring criteria for each figure with a maximum total score of 11 points were used.

Attention/Working Memory

The WAIS-III Digit Span Test was administered and scored using standard procedures. Digit Span Test requires a participant to repeat number sequences of increasing length immediately after hearing the number sequence.

Floor scores were assigned in all neuropsychological tests whenever the participant did not understand the instructions for administration, quit the test before finishing, or became confused during the test. In addition, floor scores were assigned on the Trail Making Tests when the participant was unable to complete the test in the time allowed.

Dementia Status Assessment

Neurological examiners (trained physicians or nurse practitioners) performed a structured neurological examination, which included mental status testing which covered multiple domains including memory, language, orientation, calculations, and others. Examiners also had access to the participants' MMSE and 3MS scores and their responses to selected items of the Functional Activities Questionnaire (FAQ; Pfeffer, 1982), Activities of Daily Living (ADL; Katz, 1963), and Clinical Dementia Rating (CDR; Morris, 1993) from that day to determine dementia status. Although designed as self-report instruments, the examiners asked the questions of the participants. When available at the time of the visit, informants were asked the same questions regarding the participants' functional abilities. The neurological examiner's trained judgment was used to differentiate functional loss due to cognitive impairment from physical impairment. The neurological examiners were blinded to all neuropsychological test results other than the MMSE and 3MS. Based on the participant's cognitive and functional status during the neurological evaluation, the examiner determined the presence or absence of dementia applying Diagnostic and Statistical Manual of Mental Disorders, 4th edition (DSM-IV; American Psychiatric Association, 1994) criteria. Participants meeting DSM-IV criteria for dementia were excluded from this study (N=142). Of the participants included (N=339), 47% were deemed to have normal cognition and 53% had some cognitive or functional loss but not of sufficient severity to meet DSM-IV criteria for dementia (Cognitively Impaired-Not Demented, CIND).

Data Analysis

Means, standard deviations, and percentiles (5, 10, 25, 50, 75, 90 and 95%) were derived for the overall sample and stratified according to age in groups of approximately similar size (90-91, 92-94, and 95+). The effect of age was assessed in a regression analysis with age as a continuous variable. The age-adjusted independent effects of gender, education ($\leq$ high school, some college to college graduate, and some graduate school or higher), and GDS score (<4 vs. ≥ 4) were assessed by multiple regression analyses with categorical covariates. A GDS score of 4 was selected as a cutoff for depression based on published data in elderly populations (de Craen, 2003). All statistical analyses were performed using SAS software version 8.01 for Windows (SAS Institute Inc., Cary, NC).

RESULTS

Characteristics of the first 339 non-demented participants in the 90+ Study who completed the neuropsychological battery are shown in Table 2. The sample included 231 women and 108 men with an average age of 94 (range 90 – 103). The majority of participants were living in the community and 52% lived alone. Almost half of participants reported a history of heart disease and nearly one-third a history of cancer. All subjects were Caucasian, although two participants also identified themselves as Hispanic or Latino.

Normative data for the sample by age categories are shown in Table 3. Performance declined with increasing age for more than two-thirds of the tests. Age was significantly associated with performance on the MMSE, 3MS, BNT, Animal Fluency, all CVLT tests, TMT A & B, Clock Drawing Test, and Digit Span Backward. Gender, education, and depressive state were also related to test performance. After adjusting for age, women scored on average significantly better than men on the MMSE (women=26.4 vs. men=25.6, p=0.03), CVLT Trial 4 (women=6.5 vs. men=6.0, p=0.04), CVLT Sum (women=22.7 vs. men=21.0, p=0.02), CVLT Long Delay (4.8 vs. 4.1, p=0.03), CVLT Cued Long Delay (5.4 vs. 4.5, p<0.01), and TMT A (66.1 vs. 75.3, p=0.05). Education was associated with performance on five tests. Age-adjusted scores increased with higher education on the 3MS (p for trend <0.001), BNT (p for trend=0.03), Animal Fluency (p for trend<0.01), Letter F Fluency (p for trend<0.001), and Clock Drawing Test (p for trend=0.03). After adjusting for age, subjects with GDS scores >= 4 had poorer scores on the 3MS (85.8 vs. 89.7, p<0.01), Animal Fluency (11.4 vs. 13.5, p<0.001), and Clock Drawing Test (4.9 vs. 5.6, p=0.03). The neuropsychological scores of the 76 participants who did not complete the GDS were more similar on all tests to those participants scoring ≥ 4 (results not shown).

Table 4 shows the percentage of people completing each procedure and the reasons for failure to complete. At one end of the range, most participants completed Animal Fluency. In contrast, more than one-third of the participants were unable to complete TMT A, B, or C due to vision, fatigue, or inadequate time. Tests administered towards the end of the session, (Letter Fluency, Digit Span) were frequently not completed because the testing took longer than the subject expected or the subject complained of fatigue.

DISCUSSION

The current study extends the available norms on a comprehensive battery of neuropsychological tests to people 90 years and older. Data on ten widely available and well-established neuropsychological instruments were collected from over 300 non-demented individuals in this age group. These tests span seven cognitive domains (*i.e.*, global cognition, language, recent memory, executive function, psychomotor speed, visual-spatial ability, and attention / working memory) commonly impaired in AD and other dementias. We made considerable effort to keep total administration time fairly short (approximately 1 hour), minimize fatigue, and compensate for any sensory losses in vision and hearing that might compromise performance. Overall, the oldest-old participants received the battery favorably.

The number of individuals in this study is considerably larger than other published normative studies. A comprehensive review (Mitrushina, 1999) of the existing normative data for many commonly utilized neuropsychological instruments included six tests in the current battery (BNT, Verbal Fluency, CVLT, TMT A & B, Clock Drawing Test). Without exception, reviewed studies had small samples of the oldest-old. For example, of 24 studies evaluating the TMT, only two studies included individuals 90 years and older. Moreover each of these studies included only a few individuals in this age range: 21 subjects aged 85-94, (Ivnik, 1996) and 50 subjects aged 81-91 (Richardson, 1996). Another study on older adults (age range 62-95 years) residing in retirement villages and hostels in Australia gathered normative data for several neuropsychological tests (Anstey, 2000). However, the number of participants in the oldest age range (90-95) was very small; at most 23 individuals over 90 years of age contributed data for any given instrument. Thus, the numbers of 90+ participants have been too small to generalize findings.

Individuals' scores on the neuropsychological tests in the present study were influenced by age, gender, education, and affective state. Performance decreased significantly with increasing age on approximately two-thirds of the tests in the battery, namely the MMSE, 3MS, BNT, Animal Fluency, CVLT, TMT Parts A and B, Clock Drawing Test, and Digit Span Backwards. Thus advancing age affected test scores in all domains. Women had better performance on the CVLT, MMSE, and TMT A. Despite a relatively narrow range of education in this sample, individuals with more schooling significantly outperformed their less educated peers on the 3MS, BNT, Animal and Letter Fluency, and the Clock Drawing tests.

In the current investigation, participants with four or more depressive symptoms on the GDS had lower scores on the 3MS, Animal Fluency, and Clock Drawing. This suggests that mood may affect cognitive performance in the oldest-old. However, the cross-sectional design of our study and our use of a brief screening instrument that provided a measure of depressive symptoms rather than a comprehensive psychiatric evaluation limit definitive conclusions. Furthermore, other studies present conflicting results of the relation between depression and neuropsychological functioning in the oldest-old. Palsson (2000) reported a poorer cognitive performance in depressed versus non-depressed oldest-old participants, whereas Backman (1996) did not find an association between level of depression and neuropsychological functioning. Given the mixed results across studies, the effects of depression in the oldest-old age group need to be studied using larger and more diverse samples that include formal mood and cognitive evaluations.

Despite our best efforts to design a battery of neuropsychological measures appropriate for use with the oldest-old, some of the participants were not able to complete all ten tests. Since individuals with any co-morbidity including visual or hearing impairments were not excluded, subjects may not have been able to complete specific tests. Approximately 37% of non-demented 90+ participants failed to complete TMT A, TMT B, or both despite these tests being positioned halfway through the battery. Problems with visual disabilities (11%), fatigue (8%), and lack of time (10%) accounted for much of the missing data in TMT B, but a significant number of participants either refused to do the test (7%) or failed to complete it for other reasons (3%). Since the TMT A and B measure executive functioning, this may represent a significant decline in frontal lobe function associated with extreme aging. It is interesting to note that we did not see a similar effect of age on TMT C, which primarily measures motor speed. Also, as apparent in Table 5, individuals who completed specific tests demonstrated higher levels of cognitive performance as measured by both the MMSE and the 3MS than individuals who failed to complete them. Lower global cognitive ability may be associated with failure to complete individual neuropsychological tests. For example, for TMT B 55% of non-completers were CIND, while 45% of non-completers were classified as normal. As individuals experience cognitive declines, they may be more likely to refuse or may experience fatigue more rapidly in the testing environment and be less likely to complete some components of the neuropsychological battery.

Norms for neuropsychological tests are useful to the extent that they can be generalized. To examine the representativeness of the 339 older participants in this study, we compared their demographic characteristics to those of 90+ year-old individuals in the general US population. In the 2000 U.S. Census, the vast majority (89%) of the 90+ adults in the United States were Caucasian, with the remaining comprised of 8.5% Black, 2% Asian, and 0.6% Native American or Inuit. Seventy-six percent of all 90+ year olds were female regardless of race. Thus, our sample largely reflects the current composition of the 90+ population in the U.S. Investigations in other ethnic / racial groups and in less-educated populations will be needed particularly since these demographics are likely to change in the future.

In conclusion, this study describes a battery of neuropsychological tests selected and modified for use in very elderly adults. Strengths of the battery include its relative brevity, use of multiple well-established, widely utilized, and readily available instruments, and capacity to assess a broad range of cognitive domains. This study provides normative data for these neuropsychological tests from the largest group of 90+ year-old individuals published to date. These results provide a foundation for the evaluation of cognitive functioning in the rapidly growing number of individuals in their tenth decade and beyond.

References

American Psychiatric Association. (1994). *Diagnostic and Statistical Manual of Mental Disorders: DSM-IV* (4th ed.). Washington, DC: American Psychiatric Association.

Anstey, K. J., Matters, B., Brown, A.K., & Lord, S.R. (2000). Normative data on neuropsychological tests for very old adults living in retirement villages and hostels. *The Clinical Neuropsychologist, 14*, 309-317.

Army Individual Test Battery. (1944). *Manual of Directions and Scoring*. Washington DC: War Department, Adjutant General's Office.

Backman, L., Hassing, L., Forsell, Y., & Viitanen, M. (1996). Episodic remembering in a population-based sample of nonagenarians: Does major depression exacerbate the memory deficits seen in Alzheimer's disease? *Psychology and Aging, 4*, 649-657.

Benton, A. L., & Hamsher, K. S. (1989). *Multilingual aphasia examination* (2nd. ed.). Iowa City: AJA Associates.

de Craen, A. J. M., Heeren T.J., & Gussekloo, J. (2003). Accuracy of the 15-item Geriatric Depression Scale (GDS-15) in a community sample of the oldest-old. *International Journal of Geriatric Psychiatry, 18*, 63-66.

Delis, D., Kaplan, E., & Kramer, J.H . (2001). *The Delis-Kaplan Executive Function System (DK-EFS)*. San Antonio, TX: Psychological Corporation, a Harcourt Assessment Company.

Delis, D., Kramer J.H., Kaplan E., Ober B.A. (1987). *California Verbal Learning Test: adult version*. San Antonio, TX: The Psychological Corporation.

Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (2000). *California Verbal Learning Test - Second Edition - Adult Version (CVLT-II-A): Manual* (Second ed.). San Antonio, TX: Psychological Corporation.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state" A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189-198.

Freedman, M., Leach, L., Kaplan, E., Winocur, G., Shulman, K., & Delis, D. C. (1994). *Clock Drawing: A Neuropsychological Analysis*. New York, Oxford: Oxford University Press.

Grober, E., & Buschke, H. (1987). Genuine memory deficits in dementia. *Developmental Neuropsychology, 3*, 13-36.

Ivnik, R., Malec, J.F., Smith G.E., Tangalos, E.G., & Peterson, R.C. (1996). Neuropsychological tests' norms above age 55: COWAT, BNT, MAE Token, WRAT-R Reading, AMNART, STROOP, TMT, and JLO. *The Clinical Neuropsychologist, 10*, 262-278.

Kaplan, E., Goodglass, H., & Weintraub, S. (1978). *The Boston Naming Test*. Boston: Kaplan & Goodglass.

Katz, S., Ford, A. B., Moskowitz, R. W., Jackson, B. A., & Jaffe, M. W. (1963). Studies of illness in the aged. The index of ADL: A standardized measure of biological and psychosocial function. *Journal of the American Medical Association, 185*, 914-919.

Kluger A, F. S., Golomb J., Mittelman M.S., Reisberg B. (1999). Neuropsychological prediction of decline to dementia in nondemented elderly. *Journal of Geriatric Psychiatry & Neurology, 12*, 168–179.

Lichtenberg, P. A., MacNeill, S.E. (2003). Streamlining assessments and treatments for geriatric mental health in medical rehabilitation. *Rehabilitation Psychology, 48*, 56-60.

Mack, W. J., Freed, D. M., Williams, B. W., & Henderson, V. W. (1992). Boston Naming Test: Shortened versions for use in Alzheimer's disease. *Journal of Gerontology, 47*, P154-P158.

McKhann, G., Drachman, D., Folstein, M., Katzman, R., Price, D., & Stadlan, E. (1984). Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA work group under the auspices of Department of Health and Human Services Task Force on Alzheimer's disease. *Neurology, 34*, 939-944.

Mitrushina, M. N., Boone, K.B., D'Elia, L.F. (1999). *Handbook of Normative Data for Neuropsychological Assessment.* New York: Oxford University Press.

Morris, J. C. (1993). The Clinical Dementia Rating (CDR): Current version and scoring rules. *Neurology, 43*, 2412-2414.

Morris, J. C., Heyman, A., Mohs, R. C., Hughes, J. P., van Belle, G., Fillenbaum, G., Mellits, E. D., & Clark, C. (1989). The Consortium to Establish a Registry for Alzheimer's Disease (CERAD). Part I. Clinical and neuropsychological assessment of Alzheimer's disease. *Neurology, 39*, 1159-1165.

Morris, J. C., Mohs, R., Rogers, H., Fillenbaum, G., & Heyman, A. (1988). Consortium to establish a registry for Alzheimer's Disease (CERAD): clinical and neuropsychological assessment of Alzheimer's Disease. *Psychopharmacology Bulletin, 24*, 641-652.

Paganini-Hill A, Chao A., Ross RK, Henderson BE. (1989). Aspirin use and chronic diseases: a cohort study of the elderly. *British Medical Journal, 299*, 1247-1250.

Paganini-Hill A, Ross RK, Henderson BE. (1986). Prevalence of chronic disease and health practices in a retirement community. *Journal of Chronic Diseases, 39*, 699-707.

Palsson, S., Johansson, B., Berg. S., & Skoog, I. (2000). A population study on the influence of depression on neuropsychological functioning in 85-year-olds. *Acta psychiatrica Scandinavica, 3*, 185-193.

Petersen, R. C., Smith, G. E., Ivnik, R. J., Kokmen, E., & Tangalos, E. G. (1994). Memory function in very early Alzheimer's disease. *Neurology, 44*, 867-872.

Pfeffer, R. I., Kurosaki, T. T., Harrah, C. H., Chance, J. M., & Filos, S. (1982). Measurement of functional activities in older adults in the community. *Journal of Gerontology, 37*(3), 323-329.

Putnam, S., and DeLuca J. (1990). The TCN professional practice survey, 1: General Practices of Neuropsychologists in Primary Employment and Private Practice? *The Clinical Neuropsychologist, 4*, 199-244.

Randolph, C. (1998). *RBANS Manual: Repeatable Battery for the Assessment of Neuropsychological Status.* San Antonio, TX: Psychological Corporation (Harcourt).

Reitan, R. (1985). *The Halstead-Reitan neuropsychological test battery : theory and clinical interpretation*. Tucson: Neuropsychology Press.

Richardson, E., Marottoli, RA. (1996). Education-specific normative data on common neuropsychological indices for individuals older than 75 years. *The Clinical Neuropsychologist, 10*, 375-381.

Rouleau, I., Salmon, D. P., Butters, N., Kennedy, C., & McGuire, K. (1992). Quantitative and qualitative analyses of clock drawings in Alzheimer's and Huntington's disease. *Brain and Cognition, 18*, 70-87.

Teng, E. L., & Chui, H. C. (1987). The Modified Mini-Mental State (3MS) Examination. *Journal of Clinical Psychiatry, 48*, 314-318.

U.S. Census Bureau. (2001). *Census 2000 Summary File 2-United States.* Retrieved from http://www.census.gov/Press-Release/www/2001/sumfile2.html.

Wechsler, D. (1981). *Wechsler Adult Intelligence Scale-Revised*. San Antonio, Texas: The Psychological Corporation - Harcourt, Brace, Jovanovich.

Wechsler, D. (1997a). *WAIS-III Administration and Scoring Manual*. San Antonio: The Psyhcological Corporation- Harcourt Brace & Co.

Wechsler, D. (1997b). *Wechsler Memory Scale (WMS)* (3rd ed.). San Antonio: The Psychological Corporation- Harcourt Brace & Co.

Yesavage, J. A., Brink, T. L., Rose, T. L., Lum, O., Huang, V., Adey, M., & Leirer, V. O. (1982). Development and validation of a geriatric depression screening scale: a preliminary report. *Journal of Psychiatric Research, 17*, 37-49.

TABLE 1. Neuropsychological battery

Tests in order of administration	*Range of scores*	*Unit*
MMSE	0 – 30	Points
3MS	0 – 100	Points
Animal Fluency	0 – max	No. words in 1 minute
CVLT	0 – 9	No. of words
Trial 1	0 – 9	No. of words
Trial 4	0 – 9	No. of words
Sum 1-4	0 – 36	No. of words
Long Delayed	0 – 9	No. of words
Cued Long Delayed	0 – 9	No. of words
Clock Drawing	0 – 8	Points
Trail Making Test		
Part A	1 – 180	Seconds
Part B	1 – 300	Seconds
Part C	1 – 180	Seconds
CERAD Constructions	0 – 11	Points
BNT	0 – 15	No. of items
Letter F Fluency	0 – max	No. words in 1 minute
Digit Span		
Forward	0 – 16	Points
Backward	0 – 14	Points
Total	0 – 30	Points

Note: MMSE=Mini-Mental State Examination. 3MS=Modified Mini-Mental State Examination. CVLT=California Verbal Learning Test. CERAD=Consortium to Establish a Registry for Alzheimer's disease. BNT=Boston Naming Test

TABLE 2. Characteristics of participants

Characteristic	*No.*	*%*
Gender		
Men	108	32
Women	231	68
Age (years)		
90 – 91	93	27
92 – 94	133	39
≥95	113	33
Residence		
Alone	177	52
With spouse	62	18
With relatives or friends	28	8
In household with paid care-giver	15	4
Institution or group home	57	17
Education		
High school graduate or less	98	29
Some college to college graduate	157	46
Some graduate school or higher	84	25
GDS Score[1]		
< 4 depressive symptoms	197	75
≥ 4 depressive symptoms	66	25
Medical History[2]		
Heart disease[3]	148	46
Cancer (other than skin)	96	30
Stroke	35	10
Diabetes	15	4
Depression	46	14

[1] GDS score missing for 76 participants. [2] Missing data for heart disease (16), cancer (22), stroke (3), diabetes (3), depression (7). [3]Includes: coronary artery disease, myocardial infarction, atrial fibrillation or other arrhythmias, heart valve disease, and congestive heart failure.

TABLE 3. Distribution of scores by age categories

Test	*Age category[1]*	*No.[2]*	*Mean*	*SD*	*5%*	*10%*	*25%*	*50%*	*75%*	*90%*	*95%*	*p-value[3]*
Global cognition[4]												
MMSE	90–91	83	26.8	2.9	22	23	25	27	29	30	30	<0.001
	92–94	116	26.3	2.5	21	23	25	27	28	29	30	
	95+	95	25.2	2.8	19	22	24	26	27	28	29	
	Overall	294	26.1	2.8	21	23	25	27	28	29	30	
3MS	90–91	82	89.9	8.0	76	81	86	91.5	96	98	99	<0.001
	92–94	116	89.4	7.5	75	79	87	90	95	97	98	
	95+	94	84.7	9.6	64	72	80	86.5	91	96	96	
	Overall	292	88.0	8.6	70	78	83.5	89	95	97	98	
Language												
BNT	90–91	71	12.1	2.8	6	8	11	13	14	15	15	0.05
	92–94	96	11.9	2.4	8	9	11	12	14	15	15	
	95+	54	11.3	2.4	7	8	9	11	13	14	15	
	Overall	221	11.8	2.6	7	8	11	12	14	15	15	
Animal Fluency	90–91	93	13.3	4.9	5	7	10	13	16	20	22	<0.001
	92–94	131	13.3	4.1	7	8	10	13	16	18	20	
	95+	111	11.3	3.5	6	7	9	11	14	16	17	
	Overall	335	12.6	4.2	6	8	10	12	15	18	20	
Letter F Fluency	90–91	79	11.6	4.2	4	7	9	12	14	17	20	0.18
	92–94	102	11.3	4.2	5	6	8	11	15	17	18	
	95+	77	10.8	4.0	4	6	8	11	13	16	18	
	Overall	258	11.3	4.1	4	6	8	11	14	17	18	
Recent memory												
CVLT Trial 1	90–91	74	4.3	1.6	2	2	3	4.5	5	6	7	<0.01
	92–94	113	4.1	1.6	1	2	3	4	5	6	6	
	95+	64	3.6	1.6	1	2	2	4	5	5	6	
	Overall	251	4.0	1.6	1	2	3	4	5	6	7	
CVLT Trial 4	90–91	74	6.7	1.8	4	4	6	7	8	9	9	<0.001
	92–94	113	6.6	2.0	3	4	5	7	8	9	9	
	95+	64	5.8	2.0	0	4	5	6	7	8	8	
	Overall	251	6.4	2.0	3	4	5	7	8	9	9	
CVLT Sum 1-4	90–91	74	23.6	5.2	13	16	20	25	27	29	30	<0.001
	92–94	113	22.5	6.2	12	16	19	23	27	30	32	
	95+	64	20.5	6.3	8	13	18	21	24	28	30	
	Overall	251	22.3	6.1	12	15	19	23	27	29	31	
CVLT Long Delayed	90–91	74	5.2	2.6	0	1	4	5.5	7	8	9	<0.001
	92–94	111	4.5	2.7	0	1	2	5	6	8	9	
	95+	64	4.0	2.5	0	0	2	4	6	7	8	
	Overall	249	4.6	2.6	0	0	3	5	7	8	8	
CVLT Cued Long Delayed	90–91	73	5.6	2.3	1	2	4	6	7	8	9	<0.01
	92–94	111	5.1	2.4	0	2	3	5	7	8	9	
	95+	64	4.7	2.3	0	1	3.5	5	6	8	8	
	Overall	248	5.2	2.4	0	2	4	5	7	8	9	

(Continued)

TABLE 3. Distribution of scores by age categories (Continued)

Test	*Age category*[1]	*No.*[2]	*Mean*	*SD*	*5%*	*10%*	*25%*	*50%*	*75%*	*90%*	*95%*	*p-value*[3]
Executive function												
Trails A	90–91	65	60.7	28.9	120	97	76	51	44	36	31	<0.001
	92–94	84	64.9	29.3	128	90	78	58	47.5	33	30	
	95+	56	84.8	43.2	180	171	104	71.5	53	42	37	
	Overall	205	69.0	34.8	152	115	81	58	46	36	31	
Trails B	90–91	65	185.0	82.4	300	300	300	179	112	90	87	<0.001
	92–94	78	201.4	77.7	300	300	300	191.5	130	114	103	
	95+	51	241.1	77.5	300	300	300	300	168	124	97	
	Overall	194	206.4	81.8	300	300	300	198	127	106	89	
Visual-spatial												
Clock Drawing	90–91	78	5.7	2.1	1	3	4	6	7	8	8	<0.01
	92–94	106	5.5	1.9	2	3	4	6	7	8	8	
	95+	79	5.1	2.1	1	2	4	6	7	8	8	
	Overall	263	5.4	2.0	2	3	4	6	7	8	8	
Constructions	90–91	65	9.1	1.5	7	8	8	9	10	11	11	0.12
	92–94	87	8.8	1.6	6	7	8	9	10	10	11	
	95+	67	8.6	1.6	5	7	8	9	10	10	10	
	Overall	219	8.8	1.6	6	7	8	9	10	10	11	
Attention / working memory												
Digit Span Forward	90–91	35	9.2	2.6	5	7	8	8	10	14	15	0.99
	92–94	38	9.1	2.1	6	6	8	9	10	12	13	
	95+	20	9.3	2.0	6.5	7	8	9.5	10	12	13	
	Overall	93	9.2	2.2	6	7	8	9	10	12	14	
Digit Span Backward	90–91	34	6.0	1.7	3	4	5	6	7	8	9	0.02
	92–94	38	5.6	1.9	3	3	4	6	7	8	9	
	95+	20	5.0	1.4	2.5	3.5	4	5	6	6.5	7	
	Overall	92	5.6	1.8	3	4	4	6	7	8	8	
Digit Span Total	90–91	34	15.3	3.7	10	12	13	14	17	22	22	0.20
	92–94	38	14.7	3.1	9	10	13	14.5	16	19	20	
	95+	20	14.3	2.9	9.5	10.5	12	14	16	17.5	19.5	
	Overall	92	14.8	3.3	10	11	12.5	14	16	19	21	

Note: MMSE=Mini Mental State Examination. 3MS=Modified Mini Mental State Examination. BNT=Boston Naming Test. CVLT=California Verbal Learning Test.
[1] In years. [2] Number of subjects does not always total 339 due to persons who were not administered a specific test.
[3] p-value from F-test of linear regression analysis with age as a continuous variable. [4] MMSE and 3MS were used in the determination of cognitive status.

TABLE 4. Missing data for each test

Test and Area of Cognition Tested	*Completed*[1]	*Reasons for Missing Data*[1]					
		Fatigue	*Hearing*	*Vision*	*Refused*	*Out of Time*[2]	*Other*[3]
Global Cognition							
Modified Mini-Mental	86.1	0.3	0.6	8.8	1.5	0	2.7
Language							
Boston Naming Test	72.5	7.2	0.3	8.2	3.6	7.5	0.7
Animal Fluency	98.8	0.3	0	0	0.3	0	0.6
Letter F Fluency	77.5	9.0	0	0	4.5	8.1	0.9
Recent Memory							
California Verbal Learning Test	80.2	6.1	1.0	0	3.8	9.0	0
Executive Function							
Trail Making Test A	63.3	8.0	0.3	10.2	4.6	10.5	3.1
Trail Making Test B	59.9	8.3	0.3	10.8	6.8	10.5	3.4
Psychomotor Speed							
Trail Making Test C	57.5	9.8	0.3	10.5	7.2	12.8	2.0
Visual-Spatial							
Clock Drawing	79.0	4.8	0	7.2	3.0	4.2	1.8
CERAD[3] Constructions	67.4	7.7	0	6.5	4.3	11.4	2.8
Attention / Working Memory							
Digit Span	47.7	17.1	3.1	0	5.7	22.8	3.6

Note: CERAD= Consortium to Establish a Registry for Alzheimer's disease
[1] Percentage of participants. [2] "Out of time" refers to running out of time for the entire neurological/neuropsychological assessment, not the specific test. [3] "Other" includes reasons such as equipment error, tester error, and other physical impairments such as tremors

TABLE 5. Comparison of MMSE and 3MS scores for people who completed and did not complete specific neuropsychological tests

	MMSE				*3MS*			
Test Missing	*Mean for not missing*	*Mean for missing*	*t-test*	*p-value*	*Mean for not missing*	*Mean for missing*	*t-test*	*p-value*
BNT	26.4	25.4	2.7	<0.01	89.1	85.4	3.0	<0.01
Letter F Fluency	26.3	25.6	1.6	0.12	90.0	87.6	2.8	<0.01
CVLT Long Delayed	26.3	25.5	1.8	0.07	88.6	86.3	2.0	0.05
Trails A	26.3	25.6	1.8	0.08	88.8	86.1	2.3	0.02
Trails B	26.5	25.4	2.8	<0.01	89.2	85.9	2.9	<0.01
Trails C	26.4	25.7	1.9	0.06	89.2	86.3	2.7	<0.01

Note: MMSE=Mini-Mental State Examination. 3MS=Modified Mini-Mental State Examination. BNT=Boston Naming Test. CVLT=California Verbal Learning Test-Short Form (Long Delay)