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Sources of Variation on the Mini-Mental State Examination in a Population-Based Sample of Centenarians

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Abstract

Centenarians represent a rare but rapidly growing segment of the oldest-old. This study presents item-level data from the Mini-Mental State Examination (MMSE, *M*=16.2, *SD*=8.8, Range 0–30) in a cross-sectional, population-based sample of 244 centenarians and near-centenarians (aged 98–108, 16% men, 21% African-American, 38% community-dwelling) from the Georgia Centenarian Study (2001–2008) by age, education, sex, race, and residential status. Multiple-Indicator Multiple-Causes (MIMIC) models were used to identify systematic domain-level differences on MMSE scores by key demographic characteristics in this age group. Indirect effects of age, educational attainment, race, and residential status were found on MMSE scores. Direct effects were limited to concentration for education and race, and orientation for residential status. Mean levels of cognitive functioning in centenarians were low, with mean values below most commonly-used cut-offs. Overall scores on the MMSE differed as a function of age, education, race, and residential status, with differences in scale performance limited primarily to concentration and orientation, with no evidence for interactions among centenarian characteristics. Adjusting for education was not sufficient to account for differences by race; adjusting for residential status was not sufficient to account for differences by age.

Keywords

Centenarians; MMSE; neuropsychological tests; sources of variation

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INTRODUCTION

The Mini-Mental State Examination (MMSE) is one of the most widely used assessment instruments of cognitive functioning, which screens domains of orientation to time and place, attention and memory, concentration, and language and praxis. The structure of the MMSE has been investigated with older adults in previous research using large and representative samples.[17] Previous research has also shown evidence for differences in performance in the MMSE related to a variety of factors, most consistently education and sex.[19] Other factors that are associated with differences in MMSE scores include language of administration, and race/ethnicity.[22,29] This study presents item-level descriptive statistics for the MMSE from a population-based sample of centenarians, evaluates differences in the MMSE by age, sex, race, educational attainment, and residential status, and examines systematic variations across domains of the MMSE by these characteristics.

Cognitive Functioning among Centenarians

Few studies of cognitive functioning have included large numbers of centenarians, if any. For example, data from the Epidemiologic Catchment Area (ECA) study included data from 8,556 individuals, but only 342 persons were aged 85+ and none was a centenarian.[16] Other nationally representative samples such as the Health and Retirement Study and National Long-Term Care Study, have similarly small representations of exceptional survivors.[7] This distinction is important because prevalence of cognitive impairment may continue to increase with advanced age, although incidence may level off in very late life due to increased mortality risk.[15] At the same time, increases in life expectancy indicate that the proportion of the population that can expect to reach advanced age is growing rapidly.[5]

Data on cognitive functioning from population-based samples of centenarians are just becoming available in the research literature.[6,7,24,28] These data suggest that cognitive impairment is quite prevalent in this age group, complicating presentation of normative (i.e., typical) versus normal (i.e., free from pathology) data on cognitive functioning. Further, considerable variation in cognitive functioning has been associated across a variety of dimensions. Where there are differences, higher cognitive performance is found for younger centenarians, men, Whites, individuals with higher educational attainment, and community residents.[7,24]

Research Questions

In light of the preceding literature review, the purpose of this study was to: 1) provide item-level descriptive data on MMSE scores by relevant demographic characteristics (i.e., age, educational attainment, sex, race, and residential status), and 2) identify systematic sources of variance in MMSE by key demographic characteristics with particular attention to disentangling direct and indirect effects on MMSE domain-level scores. Differences were expected to be greatest for age, educational attainment, and residential status, and smaller for race and sex.

METHODS

Sample and Design

A population-based sample of 244 centenarians (age 100+ years; n=135) and near-centenarians (age 98–99 years; n=109) from Phase III of the Georgia Centenarian Study (GCS, 2001–2008) was employed. Ages ranged from 98 to 108 years, 16% were men, 21% were African-American, and 38% lived in community settings. The study was approved by the University of Georgia Institutional Review Board on Human Subjects. Inclusion criteria for the GCS were verified age-eligibility and consent to blood draw.

Overall, 244 of the estimated 1244 (19%) of all centenarians living within the 44 county region were identified and recruited for an overall response rate of 63%. Comparison with special census tabulations indicated that, barring some minor differences (the sample of this study was somewhat older, and less likely to be men or African American than expected from 2000 census data), the sample appeared broadly representative of the characteristics of centenarians within this region including the proportion of community and facility residents.[27]

Procedures

The multidisciplinary nature of the GCS required that a data collection team meet centenarians at their residence. Data collection was divided into four sessions, each of which could be completed within two hours. On the first visit, after explaining the study aims and obtaining informed written consent, demographics, family longevity and mini-mental state examination information was collected. A second session included a blood draw and a physical examination. The third and fourth sessions focused on neuropsychological and physical functioning, respectively. The focus of the present study is only on the MMSE, drawn from the first session and for which there were complete data.

Measures

The primary outcome measure for this study was the Mini-Mental State Examination (MMSE).[11] Because of the range of cognitive functioning expected in this population, the study protocol was designed to code correct responses for the MMSE for all participants. A small number (n=21, 8.6%) of centenarians scored at floor on this measure, which was adjusted for in statistical analyses. In some cases, this was because the centenarian was non-responsive; in others, it was because the centenarian participated actively, but did not provide any correct answers. The MMSE domains of Orientation, Attention, Concentration, Memory, and Language and Praxis were coded for these analyses.[17,19] In statistical models, to adjust for floor and ceiling effects orientation, concentration, and memory scales were treated as censored below and attention and language and praxis were treated as censored above. Data were compared across the major demographic variables of age (98–99 years, n=109, 100+ years, n=135), sex (men, n=37; women, n=207), race (White, n=192; African American, n=52), residence (community, n=91; skilled nursing facility or personal care home, n=153), and educational attainment (less than high school or some high school, n=115; high school graduate or more than high school, n=122, and unknown, n=7, excluded from analyses involving education). Table 1 presents detailed demographic information.

Statistical Analysis

MMSE total scores were compared by centenarian characteristics using independent-sample t-tests for total scores and mean correct responses for 4 items, and Fisher's exact tests for item-level comparisons. Results of both tests are adjusted for multiple comparisons.[2] A domain-level multiple indicators-multiple causes (MIMIC) model was estimated to consider all five demographic characteristics simultaneously. MIMIC models can be used to identify group-level differences in latent cognitive functioning (indirect effects), as well as differential performance on the subscale level for a given level of latent cognitive functioning (direct effects, analogous to differential item functioning in the item-response context). In this context, these models are an extension to item-response theory models, but can include simultaneous tests of multiple individual characteristics. All indirect effects were freely estimated with direct paths freed based on model modification indices. As sensitivity analyses, we estimated two additional models including interactions between age and facility residence and between race and educational status. Additional models considered hearing and vision impairments, directly assessed and IRT-derived indicators of functional limitations, and scores on the Global Deterioration Rating Scale (GDRS). M*plus*

version 7 was used for all analyses. All factor loadings and model coefficients are presented as unstandardized estimates.

RESULTS

Item-Level Analyses

Proportions of correct responses to each MMSE item are provided in Table 2. In addition to the overall values, correct response rates are presented based on age group, educational attainment, sex, race, and residential status.

Age—Centenarians scored significantly lower than near-centenarians on the MMSE (*M*: 12.9 vs. 18.9, t=4.89, p=.028). Specifically, their correct response rates were lower than near-centenarians on seven out of the ten items in the domain of Orientation, one of four items in Attention, two of six items in Concentration, and three of eight items in the domain of Language and Praxis. Both age groups performed comparably on all three items in the domain of Memory.

Educational Attainment—Participants who were at least high school graduates had significantly higher MMSE scores than those with less than high school completion (*M*: 19.0 vs. 13.9, t=4.88, p<.001). Their correct response rates were higher on seven out of ten items in the domain of Orientation, all four items in Attention, five of six items in Concentration, one item in Memory, and seven of eight items in the domain of Language and Praxis.

Sex—Men had significantly higher total scores than women on the MMSE (*M*: 18.8 vs. 15.7, t=2.28, p=.041). However, Fisher's exact tests did not show men performed better than women on any particular item on the MMSE.

Race—African Americans had significantly lower scores on the MMSE than whites (*M*: 11.8 vs. 17.4, t=3.86, p<.001). Their correct response rates were lower on four out of ten items in the domain of Orientation, three out of four items in Attention, five of six items in Concentration, one item in Memory, and five of eight items in the domain of Language and Praxis.

Residential Status—Facility residents obtained significantly lower total scores on the MMSE than centenarians living in the community (*M*: 13.8 vs.20.2, t=6.20, p<.001). Their correct response rates were lower on all items in the domains of Orientation and Attention, three of six items in Concentration, one item in Memory, and seven of eight items in the domain of Language and Praxis.

Domain-Level MIMIC Models

In order to identify sources of variation on the MMSE, the effects of age, education, sex, race, and residential status were tested in a single (multivariate) multiple-indicator multiple-cause (MIMIC) model. A single-factor model was tested using the five domain summed scores as manifest indicators of latent cognitive functioning. The domain-level MIMIC model fit the data adequately (χ^2 [22]=18.86, p =.654; RMSEA=.001 [90%CI: .001, −.045]; CFI=.99; TLI=.99). All five domain scores (i.e., Orientation, Attention, Memory, Concentration, and Language and Praxis) loaded significantly on the cognitive functioning factor ($0.70 \leq |b| \leq 1.42$, p<.001). Model coefficients are shown in Table 3, the MIMIC model is presented in Supplemental Figure 1, and the subscale-level descriptive statistics are presented in Supplemental Table 1.

Age—There was a significant indirect effect of age on MMSE scores, such that centenarians scored significantly lower than near centenarians (b=−1.08 [95%CI: −1.74, −0.43], z=−3.23, p=.001). There were no significant direct effects of age on any of the five domain scores, suggesting that the effect of age on the five domains of ability was all indirectly through the latent factor, cognitive functioning.

Educational Attainment—There was a significant indirect effect of educational attainment on cognitive performance such that individuals who were at least high school graduates scored significantly higher than those who had not graduated from high school (b=1.09 [95%CI: 0.39, 1.80], z=3.04, p=.002). Consistent with past research, a direct effect of educational attainment was also found on the domain of Concentration (b=0.76 [95%CI: 0.05, 1.48, z=2.09, p=.036).

Sex—There was no significant indirect effect of sex on cognitive performance (b=−0.82 [95%CI: −1.71, −0.07], z=−1.81, p=.071). There were also no significant direct effects of sex on any of the five domain scores.

Race—There was a significant indirect effect of race on cognitive performance such that African Americans scored lower than whites (b=−0.87 [95%CI: −1.73, −0.01], z=−1.98, p=.048). There was a direct effect of race on the domain of Concentration (b=−1.28 [95%CI: −2.39, −0.17], z=−2.27, p=.023) with African Americans scoring lower on Concentration than Whites with equal cognitive abilities.

Residential Status—There was a significant indirect effect of residential status on cognitive performance such that facility residents scored lower than community residents (b=−1.21 [95%CI: −1.95, −0.47], z=−3.19, p=.001). There was also a significant direct effect of residential status on the domain of Orientation (b=−1.07 [95%CI: −1.88, −0.25], z=−2.57, p=.010) with facility residents scoring lower than community residents with equal cognitive abilities.

There were no direct or indirect effects associated with either hearing or vision impairments (study protocol included amplification devices and large-format stimuli). Likewise, there were no direct effects associated with IRT-derived or directly assessed functional status, or GDRS scores. Two additional models including age×facility residence and race×education were also estimated. Neither interaction effect was significant (results not presented), although we note that educational quality may be more meaningful than years of formal education in this sample.

DISCUSSION

Although it was originally designed as a screening tool,[30] the MMSE is one of the most widely used global measures of cognitive functioning. The purpose of this study was to provide item-level descriptive data on MMSE scores by age, educational attainment, sex, race, and residential status in a population-based sample of centenarians, and identify direct and indirect sources of variance in MMSE domains by age, educational attainment, sex, race, and residential status.

This study extends descriptive population-based item-level data on the MMSE to a higher age range than currently available in the literature. Holtsberg et al, for example, only considered community-dwelling centenarians selected to have MMSE scores of 21 or higher.[12] Building on Jones and Gallo's prior work,[19] whose data did not contain any centenarians, this study provided proportions of correct responses across age, education, and

sex for this age group. As well, we extend these characteristics to also include variations by race, and residential status.

Considerable prior research has demonstrated differences in MMSE scores, most consistently by age, education, and sex. For example, in a community-based study of MMSE in residents over 65 years of age in northern Japan, Ishizaki and colleagues found that all item scores except for that of naming were affected by both age and educational level.[14] Similar education- and age-related differences in the MMSE were found in the sample of over 65 year old participants in the Canadian Study of Health and Aging,[4] and in a sample of healthy Brazilian adults.[20] Jones and Gallo examined differential item functioning related to education, race, and sex in the MMSE with a sample aged 50–85 years and found DIF related to education and sex for a majority of items.[19] The memory domain of the MMSE, however, seems to be less affected by educational attainment. Matallana and colleagues found that the better-educated participants in their study performed better than those with less education in total MMSE and the non-memory domains.[23]

Older individuals generally score lower on the MMSE than younger individuals, suggesting that age-specific norms may be of value when interpreting MMSE scores to understand cognitive functioning in different age groups.[3,4,20] A recent study of 68 centenarians in Japan found that centenarians scored significantly lower than their younger elderly counterparts (i.e., aged 60–74 years and 75–89 years) in most of the domains in the MMSE.[13] This age disparity calls for more finely-grained investigation in performance differences in the MMSE for this age group. It is important to examine sources of variation not only at the scale level but also at the sub-domain level, in order to see whether the MMSE is associated with educational attainment, sex, race, and some other relevant variables for the centenarians. Finally, because the previous research demonstrates clear age differences even in this age-restricted sample,[13,24] differences in performance by age were considered. Consistent with this research, indirect effects of both age and educational attainment on MMSE scores were identified, as well as indirect effects of education on concentration.

Some prior research suggests differences by sex in the MMSE for older adults.[1,4] Sex-related differences existed for some items in the MMSE (e.g., calculation and spelling backward), and the differences persisted after controlling for dementia.[26] When differences are found, they generally favor men, however differences associated with measurement non-invariance and prediction non-invariance cannot be ruled out. In their study of older adults, Jones and Gallo found that the negative correlations between MMSE and age as well as functional disability were stronger for women than for men.[18] Among centenarians, no evidence for differences by sex in the MMSE was observed, although it is worth noting that the proportion of centenarians who are men (15%) is rather low, which limits the magnitude of difference that can be reliably detected.

A few studies document influences on performance in the MMSE by race, ethnicity, and language of administration.[8,9,22,25,29] In their sample of 604 African American and 1,077 White elders, Fillenbaum et al. found race differences such that African Americans tended to score lower than Whites on the MMSE, in addition to associations with education and age.[10] Similar to this past research, race differences were also found favoring Whites over African Americans. Differences were found in both indirect effects and a direct effect on concentration. Differences were similar in magnitude and structure to what was found for education, which was also adjusted in the MIMIC models in this study, suggesting that educational differences alone do not appear to fully explain these differences.

Unique to this study was the ability to consider facility versus community residence as it relates to performance on the MMSE. In contrast to individuals 80–89 years of age, where approximately 15% of the population lives in facilities, more than half of centenarians live in personal care homes or skilled nursing facilities.[21] Unlike with younger samples, there is greater overlap than difference between community and facility residing centenarians. For example, on some domains, such as nutritional status, facility residents actually have better status than those living in their own homes.[16] In the present study, it was not possible to separate groups on the basis of care received (in home or facility). However, sensitivity analyses did not suggest any direct effects on the basis of directly assessed or item-response theory-derived measures of physical performance. Significant indirect effects of facility residence on MMSE scores were identified, as well as significant direct effects on the domain of orientation, consistent with the expectation that facility residents would have both greater cognitive impairment and fewer exposures to orienting cues. Given evidence that orientation scores differ between institutionalized and community-dwelling centenarians, for a given level of latent ability, clinicians should be aware of these differences and perhaps place less emphasis on these items when interpreting MMSE data for institutionalized centenarians. In particular, given the difference on measures of orientation and the possible reductions in temporal and spatial prompts to which residents are exposed, the data of the current study suggest this may be a potential intervention target within such facilities.

The present results offer several concrete clinical recommendations. First, mean cognitive performance on the MMSE is substantially lower in centenarians than in younger age groups, which will be important to recognize as clinicians see more centenarians in clinical practice. Second, there are important group differences in cognitive functioning (indirect effects) by age, education, race, and residential status with individuals over age 100 years, with less than high school education, African Americans, and facility residents demonstrating lower cognitive function. The magnitude of these differences is moderate in size, with standardized effect sizes ranging from approximately 0.34 *SD* for race to 0.48 *SD* for facility residence. Third, we find evidence for differential performance (direct effects) by education, race, and residential status. At comparable levels of cognitive functioning, individuals with less than high school education will score approximately 0.8 points lower on concentration than high school graduates; African Americans will score approximately 1.3 points lower on concentration than Whites; facility residents will score approximately 1.1 points lower on orientation than community residents. Clinicians may wish to consider scores that adjust for these potential sources of bias in light of additional clinical evidence. These findings also suggest that use of large-format stimuli and amplification equipment can eliminate performance differences as a function of sensory impairments in this population.

Finally, there are several limitations in the present study. Sample size is small. However, the current population of centenarians also is very small, and nearly 20% of the entire estimated population in this targeted geographic area was recruited. The present study employed numbers of centenarians that are comparable to or exceed the Health and Retirement Study (n=143) and the 2004 wave of the National Long Term Care Survey (n=253) which oversampled individuals 95 years of age and older. These limitations necessitated that analyses be conducted using domain scores rather than at the item-level, but the effects of all demographic characteristics were considered simultaneously in the model.

Conclusions

Mean levels of cognitive functioning among centenarians are low, consistent with a high level of cognitive impairment, as expected. The present sample consists of a mixture of cognitively intact (although often low-functioning) and cognitively impaired individuals.[28] Distinguishing between these groups of individuals is complicated by the absence of

established cut-offs on standard screening tools in this age group, and the considerable degree of overlap in cognitive performance between centenarians with and without cognitive impairment.[6] Overall, mean MMSE scores in the complete sample were very low, with the mean of 16.2 being lower than most established clinical thresholds with younger samples.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Table 1

Sample Characteristics

Respondent Characteristic	Frequency (*N*)	Percentage (%)
Total sample	244	100
Sex		
Female	207	85
Male	37	15
Age Group		
Centenarian	135	55
Near-centenarian	109	45
Race		
White	192	79
African American	52	21
Residence status		
Community	91	37
Skilled nursing facility or personal care home	153	63
Educational attainment		
High educational attainment	122	50
Low educational attainment	115	47
Unknown	7	3
Self-reported hearing problem		
Yes	85	34.8
No	131	53.7
Not sure	28	11.5
Self-reported vision problem		
Yes	87	35.7
No	129	52.9
Not sure	28	11.5
GDRS		
1	15	6.1
2	34	13.9
3	55	22.5
4	28	11.5
5	50	20.5
6	44	18.0
7	14	5.7
Missing	4	1.6
	Mean (*SD*)	Range
DAFS-IADL	26.03 (18.39)	0–58
DAFS-BDL	16.48 (8.13)	0–23
IRT-Physical Performance	5.18 (3.08)	1–12

Note. *N* = 244, ages 98–108 years. Low Educational Attainment = Less than high school or some high school. High Educational Attainment = High school graduate or postsecondary. GDRS = Global Deterioration Rating Scale. DAFS-IADL = Directly Assessed Functional Status Instrumental

Activities of Daily Living. DAFS-BDL = Directly Assessed Functional Status Basic Activities of Daily Living. IRT-Physical Performance = Item Response Theory Derived Measure of Physical Performance.

Table 2

Item-Level Response Data (MMSE Total Scores and Proportions Responding Correctly).

		Age Group			Education		
	Total (*N* = 244)	**Near-centenarian (*n*= 109)**	**Centenarian (*n*= 135)**	***p***	**High (*n*= 122)**	**Low (*n*= 115)**	***p***
MMSE Total Score (*SD*)[a]	16.20 (8.80)	18.10 (8.20)	12.90 (8.20)	**0.028**	19.00 (7.50)	13.90 (9.10)	**.001**
Orientation[b]							
What is the year	0.37	0.52	0.24	**.001**	0.48	0.26	**.001**
What season is this	0.48	0.55	0.42	.054	0.56	0.43	.051
What month is this	0.48	0.65	0.35	**.001**	0.58	0.41	**.009**
What date of the month	0.28	0.40	0.18	**.001**	0.39	0.18	**.001**
What is the day of the week	0.46	0.58	0.36	**.001**	0.53	0.40	.068
What town are we in	0.63	0.73	0.55	.005	0.71	0.57	**.031**
What county are we in	0.50	0.62	0.40	**.001**	0.58	0.43	**.019**
What state are we in	0.75	0.83	0.70	.025	0.85	0.70	**.005**
What is your home address	0.43	0.58	0.30	**.001**	0.51	0.37	**.036**
What is your phone number	0.36	0.50	0.24	**.001**	0.39	0.35	.591
Attention[b]							
Can repeat “toothbrush”	0.80	0.87	0.74	.015	0.89	0.75	**.007**
Can repeat “cigarette”	0.82	0.88	0.78	.043	0.91	0.77	**.003**
Can repeat “pen”	0.77	0.84	0.72	.033	0.87	0.70	**.002**
# of words correctly repeated[a]	2.39 (1.11)	2.59 (0.94)	2.24 (1.22)	**.012**	2.66 (0.83)	2.22 (1.23)	**.001**
Can repeat “no ifs, ands, or buts”	0.72	0.83	0.63	.001	0.87	0.57	**.001**
Concentration[b]							
First serial subtraction	0.43	0.54	0.34	**.002**	0.61	0.26	**.001**
Second serial subtraction	0.23	0.31	0.17	.010	0.32	0.16	.057
Third serial subtraction	0.20	0.28	0.14	.010	0.30	0.11	**.011**
Fourth serial subtraction	0.19	0.26	0.14	.033	0.33	0.06	**.001**
Fifth serial subtraction	0.20	0.29	0.13	**.001**	0.30	0.10	**.002**
# of correct subtractions[a]	1.26 (1.75)	1.68 (1.90)	0.92 (1.54)	**.001**	1.85 (1.93)	0.70 (1.34)	**.001**
Spells “world” backwards	0.29	0.39	0.39	.005	0.38	0.22	**.010**

		Age Group			Education		
	Total (*N* = 244)	**Near-centenarian (*n*= 109)**	**Centenarian (*n*= 135)**	***p***	**High (*n*= 122)**	**Low (*n*= 115)**	***p***
# of letters correctly spelled[a]	2.28 (2.08)	2.73 (2.08)	1.92 (2.01)	**.002**	1.76	2.88 (1.95)	**.001**
Memory[b]							
Recall “toothbrush”	0.13	0.17	0.17	.184	0.20	0.07	**.003**
Recall “cigarette”	0.18	0.24	0.13	.044	0.24	0.13	.166
Recall “pen”	0.18	0.24	0.13	.028	0.24	0.12	.115
# of items recalled[a]	0.50 (0.89)	0.66 (0.96)	0.36 (0.80)	**.010**	0.67 (1.02)	0.34 (0.71)	**.004**
Language and Praxis[b]							
Can name a “watch”	0.84	0.93	0.76	**.001**	0.93	0.76	**.001**
Can name a “pencil”	0.86	0.92	0.81	.017	0.93	0.79	**.002**
Takes paper in right hand	0.73	0.80	0.68	.043	0.78	0.70	.234
Folds in half	0.78	0.85	0.73	.019	0.85	0.72	**.017**
Puts it on the floor	0.71	0.77	0.65	.049	0.80	0.64	**.009**
Can read and follow instruction	0.73	0.84	0.63	**.001**	0.84	0.62	**.001**
Is a complete sentence	0.55	0.65	0.47	.007	0.67	0.46	**.001**
Copies the drawings of pentagons	0.19	0.28	0.11	**.001**	0.25	0.13	**.021**

	Sex			Race			Residence Status		
	Female (*n*= 207)	**Male (*n*= 37)**	***p***	**Black (*n*= 52)**	**White (*n*= 192)**	***p***	**Community (*n*= 91)**	**SNF/PCH (*n*= 153)**	***p***
MMSE Total Score (*SD*)[a]	15.7 (8.9)	18.8 (7.7)	.041	11.8 (9.0)	17.4 (8.4)	**.001**	2.2 (7.1)	13.8 (8.9)	**.001**
Orientation[b]									
What is the year	0.34	0.51	.062	0.23	0.40	**.024**	0.52	0.28	**.001**
What season is this	0.46	0.57	.285	0.39	0.51	.159	0.68	0.36	**.001**
What month is this	0.47	0.54	.480	0.33	0.53	**.012**	0.60	0.41	**.005**
What date of the month	0.27	0.32	.551	0.17	0.31	.057	0.44	0.18	**.001**
What is the day of the week	0.44	0.54	.285	0.33	0.49	.042	0.64	0.35	**.001**
What town are we in	0.61	0.73	.198	0.54	0.65	.148	0.82	0.51	**.001**
What county are we in	0.48	0.57	.376	0.33	0.54	**.008**	0.71	0.37	**.001**
What state are we in	0.73	0.89	.038	0.60	0.80	**.006**	0.91	0.66	**.001**
What is your home address	0.39	0.65	.004	0.31	0.46	.059	0.71	0.26	**.001**

	Sex			Race			Residence Status		
	Female (*n*= 207)	**Male (*n*= 37)**	***p***	**Black (*n*= 52)**	**White (*n*= 192)**	***p***	**Community (*n*= 91)**	**SNF/PCH (*n*= 153)**	***p***
What is your phone number	0.33	0.51	.040	0.25	0.39	.075	0.52	0.26	**.001**
Attention[b]									
Can repeat “toothbrush”	0.78	0.89	.180	0.67	0.83	**.018**	0.95	0.71	**.001**
Can repeat “cigarette”	0.81	0.89	.348	0.71	0.85	**.023**	0.95	0.75	**.001**
Can repeat “pen”	0.76	0.81	.672	0.69	0.79	.140	0.91	0.69	**.001**
# of words repeated[a]	2.36 (1.14)	2.59 (0.93)	.173	2.08 (1.33)	2.48 (1.03)	**.047**	2.80 (0.60)	2.15 (1.27)	**.001**
Can repeat “no ifs, ands, or buts”	0.71	0.78	.429	0.56	0.76	**.005**	0.80	0.67	**.027**
Concentration[b]									
First serial subtraction	0.39	0.68	.028	0.19	0.50	**.001**	0.54	0.37	**.040**
Second serial subtraction	0.22	0.32	.287	0.12	0.27	.032	0.35	0.16	.082
Third serial subtraction	0.17	0.38	.013	0.08	0.23	**.014**	0.31	0.14	.097
Fourth serial subtraction	0.17	0.30	.175	0.08	0.22	**.022**	0.32	0.12	**.019**
Fifth serial subtraction	0.17	0.35	.045	0.06	0.24	**.002**	0.33	0.12	**.020**
# of correct subtractions[a]	2.02 (1.98)	1.12 (1.67)	.012	1.46 (1.81)	.52 (1.24)	**.001**	1.85 (1.94)	0.91 (1.53)	**.001**
Spells “world” backwards	0.29	0.32	.695	0.09	0.34	**.001**	0.81	0.56	.112
# of letters correctly spelled[a]	2.23 (2.07)	2.57 (2.10)	.366	1.02 (1.65)	2.63 (2.05)	**.001**	2.63 (1.95)	2.08 (2.13)	.046
Memory[b]									
Recall “toothbrush”	0.13	0.14	.759	0.04	0.16	**.020**	0.20	0.09	**.001**
Recall “cigarette”	0.17	0.22	.816	0.08	0.21	.052	0.24	0.14	.606
Recall “pen”	0.15	0.32	.035	0.10	0.20	.092	0.20	0.16	.387
# of items recalled[a]	0.46 (0.86)	0.68 (1.00)	.181	0.21 (0.67)	0.57 (0.92)	**.002**	0.66 (1.01)	0.40 (0.79)	**.037**
Language and Praxis[b]									
Can name a “watch”	0.82	0.95	.054	0.69	0.88	**.003**	0.97	0.76	**.001**
Can name a “pencil”	0.84	0.97	.038	0.75	0.89	**.024**	0.97	0.79	**.001**
Takes paper in right hand	0.72	0.81	.315	0.67	0.75	.290	0.87	0.65	**.001**
Folds in half	0.78	0.78	.999	0.64	0.82	**.007**	0.90	0.71	**.001**
Puts it on the floor	0.69	0.81	.170	0.62	0.73	.124	0.84	0.63	**0.001**
Can read and follow instruction	0.71	0.81	.236	0.56	0.77	**.005**	0.89	0.63	**0.001**
Is a complete sentence	0.56	0.54	.860	0.35	0.61	**.001**	0.68	0.48	**0.002**

	Sex			Race			Residence Status		
	Female (*n*= 207)	**Male (*n*= 37)**	***p***	**Black (*n*= 52)**	**White (*n*= 192)**	***p***	**Community (*n*= 91)**	**SNF/PCH (*n*= 153)**	***p***
Copies the drawings of pentagons	0.17	0.27	.175	0.10	0.21	.071	0.25	0.15	0.062

Notes. Georgia Centenarian Study, 2001–2009. (*N* = 244, ages 98–108 years). MMSE = Mini-Mental State Examination. Education High = High School Graduate and Postsecondary; Education Low = Some High School and Less than High School. SNF/PCH = Skilled nursing facility or personal care home. Raw *p* values are presented in table. Multiple comparisons of correct item responses are adjusted using Benjamini-Hochberg Approach (1995), boldface figures indicate H_0 rejected.

[a] Independent-sample *t* tests;

[b] Fisher's exact tests.

Table 3

Model Coefficients of Domain-Score MIMIC Model with covariates—Age, Education, Sex, Race, and Facility

	Factor Loading	Age Group (Centenarian)	Education (High)	Gender (Female)	Race (African American)	Residential Status (in SNF/PCH)
Latent Factor						
Cognitive Functioning	--	−1.08 **	1.09 **	−0.82	−0.87 *	−1.21 **
Manifest Variable						
Orientation	1.42 ***	--	--	--	--	−1.07 **
Attention	1.10 ***	--	--	--	--	--
Concentration	1.00	--	0.76 *	--	−1.28 *	--
Memory	0.70 ***	--	--	--	--	--
Language and Praxis	0.89 ***	--	--	--	--	--

Notes. Model coefficients of the 5-covariate MIMIC model are estimated with censored (below) domain summed scores as the manifest variables, with the WLSMV estimator and delta parameterization. Estimates of model coefficients are unstandardized estimates. Georgia Centenarian Study, 2001–2009. (N = 244, ages 98–108 years). MIMIC = multiple indicators-multiple causes. Education (High) = High School Graduate and Postsecondary. SNF/PCH = Skilled nursing facility or personal care home.

*** $p < .001$,

** $p < .01$,

* $p < .05$.