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Research Article

Disparity in Educational Attainment Partially Explains Cognitive Gender Differences in Older Rural South Africans

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Abstract

Objectives: Direction and magnitude of gender differences in late-life cognitive function are inextricably tied to sociocultural context. Our study evaluates education and literacy as primary drivers of gender equality in cognitive performance among middle-aged and older adults in rural South Africa.

Method: Data were collected on 1,938 participants aged 40–79 from Agincourt, South Africa. Cognitive function was measured via the Oxford Cognitive Screen-Plus, a tablet-based assessment with low literacy demands. Four cognitive domains were derived through confirmatory factor analysis: episodic memory, executive function, visual spatial, and language. Structural equation models tested domain-specific gender effects, incrementally controlling for demographic, education, health, and socioeconomic variables.

Results: In the model adjusting only for demographic factors, men outperformed women on executive function and visual-spatial domains. Adding education and literacy to the model revealed a robust female advantage in episodic memory, and reduced the magnitude of male advantage in executive function and visual and spatial by 47% and 42%, respectively. Health and socioeconomic factors did not alter patterns of gender associations in subsequent models.

Discussion: In this older South African cohort, gender inequality in cognitive performance was partially attributable to educational differences. Understanding biopsychosocial mechanisms that promote cognitive resilience in older women is critically important given the predominantly female composition of aging populations worldwide.

Keywords: Cognitive aging, Education, Gender differences, Literacy, Sub-Saharan Africa

Gender differences in cognitive abilities have long been of interest to developmental scientists. Formative research revealed gender-specific patterns in the cognitive skills of children and adolescents, sparking considerable debate regarding roles of environmental versus biological mechanisms in shaping gender differences in cognition (Miller & Halpern, 2014). Recent attention has been placed on the degree to which cognitive gender differences persist into older adulthood. Gender-divergent cognitive trajectories have profound implications for managing population-level cognitive aging, given that women outlive men by several years in most of the world's aging populations (Austad &

Bartke, 2015). Research into late-life cognitive gender differences has been concentrated in higher-income countries, leaving a gap in our knowledge of how cognitive abilities of men and women are differentially affected by resource limitations. The current study investigated gender differences in language, executive function, episodic memory, and visual-spatial ability in a cohort of middle-aged and older adults in rural South Africa.

Biological and social mechanisms may contribute to the development of cognitive gender differences. Biological hypotheses suggest that gender differences in cognitive performance are the manifestation of underlying differences in biological structures and processes (Li & Singh, 2014), including sex differences in brain volume and structure, hormone levels, genetic risks, and distribution of contributory diseases (e.g., cardiovascular conditions). There is also a growing body of evidence suggesting that cognitive gender differences, particularly in late-life, are strongly influenced by societal factors. The attenuation of cognitive gender differences within countries over time provides a compelling case for the role of environmental factors in shaping male–female differences in cognition (Weber, Skirbekk, Freund, & Herlitz, 2014). Similarly, country-level attitudes toward occupational gender roles have been shown to influence the direction and magnitude of cognitive gender differences in older age (Bonsang, Skirbekk, & Staudinger, 2017).

One way to elucidate social and biological origins of cognitive gender differences is to compare gender effects across populations known to vary in terms of social policies, cultural contexts, and the distributions of specific risk factors. Findings from high-income countries have shown that older women perform as well as or better than older men on most cognitive tasks (Bonsang et al., 2017; Langa et al., 2009; Weber et al., 2014). Conversely, studies from lower-income countries report marked gender disparity in cognitive performance, even after controlling for a variety of sociodemographic factors (Lee, Shih, Feeney, & Langa, 2014; Maurer, 2011; Weir, Lay, & Langa, 2014; Yount, 2008). The few studies exploring cognitive gender differences in older African populations report higher rates of cognitive impairment among women (Guerchet et al., 2009; Ogunniyi et al., 1997; Olayinka & Mbuyi, 2014). Conflicting findings across world regions may be due to country-level differences in the resources allocated to the development of men and women, as well as study-level differences in the measures and procedures used to assess cognitive function.

Here, we investigate the role of education as the primary driver of gender disparity in late-life cognitive ability. Low- and middle-income countries are characterized by social beliefs and institutional policies that curtail educational and occupational development for women (Miller & Halpern, 2014). As education and literacy have been strongly associated with late-life cognitive function (Manly, Touradji, Tang, & Stern, 2003; Stern, 2009), differential access to educational opportunities by gender may be a key factor in the development of cognitive gender gaps throughout the lifespan. To isolate the contribution of education, our study accounts for a variety of other factors that have been linked to late-life cognitive function and may be differentially distributed by gender and country-level income, including physical and mental health and socioeconomic resources (Chen, 2016; Kobayashi et al., 2017; Panza et al., 2010; Whitmer, Sidney, Selby, Johnston, & Yaffe, 2005).

South Africa's unique political history may put older women, who came of age during Apartheid, at particular risk for late-life cognitive decline. Apartheid-era policies systematically restricted the quality of education for South Africa's black-majority population (Christie & Collins, 1982). State-run schools established for black children were gravely under-resourced, taught censored curriculum, and were logistically difficult to access, leading to low attendance rates (Christie & Collins, 1982; Kobayashi et al., 2017). Although Apartheid-era education policies were detrimental to the cognitive development of black men and women alike, deeper societal forces further limited the opportunities afforded to women (Oberhauser & Pratt, 2004). The economic structure of Apartheid required many black men to migrate to industrial areas for work, leaving women behind to play traditional household roles with little opportunity for financial independence (Oberhauser & Pratt, 2004). Patriarchal family structures and weak occupational potential diminished female incentives to pursue education, and may have contributed to differential cognitive development of males and females. In that poor early life circumstances influence late-life cognitive health (Kobayashi et al., 2017), older South African women may have experienced particularly difficult barriers to preserving late-life cognitive function.

A limitation of existing research on cognitive gender differences in older age is that many studies have relied on traditional neuropsychological measures that are known to be biased downward for participants with low levels of education and literacy (Borson, Scanlan, Watanabe, Tu, & Lessig, 2005; Chang et al., 2014; Mungas, Reed, Marshall, & Gonzalez, 2000). The use of such instruments places women, with historically lower education levels, at a distinct disadvantage. Here, we employ the Oxford Cognitive Screen Plus (OCS-Plus), a novel tablet-based assessment designed to reduce education bias by deemphasizing language and numeracy demands associated with common cognitive screening tools. The OCS-Plus includes verbal and nonverbal measures of crystallized abilities, like object naming and semantic knowledge, as well as fluid abilities, like reasoning and perceptual-motor speed. The battery was previously validated in the study population (Humphreys et al., 2017), where it was shown to have strong psychometric properties and external validity.

Few studies have investigated domain-specific differences in the cognitive performance of older men and women in sub-Saharan Africa. Comparing gender effects across multiple cognitive domains may provide insight into how education and related factors promote gender differences in performance. Although education plays a critical role in shaping a variety of cognitive skills and strategies, some neuropsychological tests are more sensitive to education and literacy effects than others. Traditionally, education was thought to have a stronger impact on test performance of verbal, crystallized abilities compared with nonverbal, fluid abilities (Ardila, Ostrosky-Solis, Rosselli, & Gomez, 2000); however, results from several studies have since questioned whether nonverbal tasks are truly free of education effects (Manly et al., 1999; Ostrosky-Solis, Ramirez, & Ardila, 2004; Rosselli & Ardila, 2003). In this study, we explore (i) the direction and magnitude of gender differences in the cognitive abilities of older rural South Africans and (ii) the extent to which education and literacy help to explain gender divergence in cognitive performance net of other demographic, health, and socioeconomic factors. Given high rates of illiteracy and low educational attainment among older women in this region, we expected the biggest male advantages in cognitive performance to emerge in cognitive domains with the strongest associations with education.

Method

Data and Participants

We utilize cross-sectional baseline data collected in 2015 from "Health and Aging in Africa: A Longitudinal Study of an INDEPTH Community in South Africa (HAALSI)." Focused on socioeconomic and biological determinants of health, HAALSI is a community-representative cohort of 5,059 middle-aged and older adults living in the Agincourt subdistrict of Mpumalanga Province, South Africa. The details of the study and sampling procedures have been published elsewhere (Gómez-Olivé et al., 2018). In brief, the sampling frame included individuals ≥40 years of age and living at the study site for at least one year prior to the start of data collection (response rate 86%). Data and questionnaires are available for public download at https://haalsi.org/data (HAALSI Study, n.d.).

In-home interviews included questionnaires, assessments of physical and cognitive function, anthropometric measurements, and blood samples for cardiometabolic conditions and human immunodeficiency virus (HIV). The current study focuses on a subsample of HAALSI participants who completed a more extensive laboratory evaluation 1–14 months after the baseline survey (M = 6 months), including the OCS-Plus.[1] Approximately half of the HAALSI sample took part in the supplemental visit (n = 2,498), among whom 2,144 (85%) completed some of the OCS-Plus. We excluded participants who were missing covariates (n = 168) or who failed to complete at least 10% of the OCS-Plus (n = 8), resulting in a final analytic sample of 1,938 participants. Excluded participants were slightly older than the analytic sample (M = 60.5 vs 58.5, respectively), but did not differ with regard to gender or cognitive screening scores from the baseline survey.

Measures

Cognitive function

The OCS-Plus was run as an offline application on Windows Surface Pro tablets, and total testing time was approximately 20–30 min. Language tests included a four-item *picture naming task* [score range = 0–4] as well as a *semantics* tasks that required participants to identify specific objects or items from a semantic category [0–4]. Awareness of time was evaluated with a four-item *orientation* task [0–4]. Episodic memory tests included two trials of a five-word *immediate recall* [0–10], a brief *delayed word recall* [0–5], and *word recognition* task [0–5]. An *incidental memory* task was also conducted, where participants were asked to identify picture and word stimuli they had previously seen but were not told to remember [0–4]. Executive function tests included a *trails* task, which required participants to connect shapes (circles and squares) on the tablet screen, first connecting circles in ascending size [0–7], then connecting squares in descending size [0–7], and then alternating between shapes while applying the conflicting size rules [0–14]. *Rule finding* required participants to predict the movement of a dot through a grid by learning and adapting to changing movement patterns. Score was based on the number of rules learned [0–5]. Visual spatial ability was evaluated with *figure copy* task where participants were asked to copy a complex figure on the tablet screen [0–21]. For *figure copy recall* [0–21], participants were shown the same figure for 2 s and were then asked to recreate the image from memory. *Auditory attention* required participants to listen to a series of audio-recorded words and make different button responses for target versus distractor words. Accuracy scores were calculated for target [0–27] and distractor trials [0–54]. See Supplementary Material for more details on task administration and individual tests.

Covariates

Primary analyses incorporated demographic, education, health, and socioeconomic covariates, collected during the main HAALSI survey unless otherwise noted.

Demographic factors

We included chronological age and marital status (Married vs Unmarried) across models. We also adjusted for country of origin (South Africa vs Other) due to the high prevalence of Mozambican immigrants in the Agincourt area (Kahn et al., 2007), who may have experienced different exposures than those born within South Africa.

[1] To maximize participation rate, the oldest participants in the subsample (aged 70–79) were invited to complete laboratory assessments in home.

Education factors
Educational attainment was indicated by two self-reported measures: years of formal education and self-rated literacy. Education was top-coded at 16 years due to low participation in higher education.

Health factors
We included a variety of health factors associated with cognitive function in adulthood. A comorbidity index (0–5) was computed as the sum of preexisting conditions, including cancer, hypertension, stroke, diabetes, and HIV.[2] Self-rated health was measured via a single question asking the participant to rate current health, recoded as a binary variable indicating good/very good health versus moderate to very bad health. Functional disability was a binary indicator of whether the participant had a limitation in any of five activities of daily living (ADLs): walking, eating, bathing, getting in/out of bed, and using the toilet. Finally, we controlled for depressive symptoms using an eight-item version of the Center for Epidemiologic Studies Depression Scale (CESD; Eaton, Smith, Ybarra, Muntaner, & Tien, 2004), where higher scores indicate higher endorsement of depressive symptoms (0–8).

Socioeconomic factors
Household wealth index was created using principal components analysis of household-level assets, vehicles, and livestock (Filmer & Pritchett, 2001), categorized into quintiles of wealth. We also included monthly household income (in South African Rand), and employment status (working vs not working).

Statistical Analysis

We examined gender differences in raw cognitive measures and covariates using independent samples *t*-test for continuous variables and chi-square test for categorical variables. Descriptive statistics were computed using STATA version 15.0.

The underlying factor structure of the OCS-Plus was tested using exploratory (EFA) and confirmatory factor analysis (CFA). We compared EFA models allowing for one to five factors, and each model was evaluated for model fit and theoretical consistency. The following model fit indices were applied: comparative fit index (CFI), Tucker–Lewis index (TLI), and root-mean-square error of approximation (RMSEA). Criteria for good model fit were CFI and TLI >0.95 and RMSEA <.06 (Hu & Bentler, 1999). Additional criteria used to determine meaningful change in model fit included (i) change in chi-square per change in degrees of freedom and (ii) change in the CFI > |0.01| (Siedlecki, Honig, & Stern, 2008). Items with weak factor loadings (<0.25) were dropped from subsequent CFA models. CFA was performed on the best fitting and most parsimonious model emerging from the EFA, allowing each variable to load onto the single factor on which it had the highest loading.

Multiple Indicators Multiple Causes (MIMIC) modeling was used to assess effects of gender and covariates on latent cognitive factors. MIMIC models are a special case of structural equational modeling designed to test the relationship between latent factors and a set of observed predictors (causes; Muthén & Muthén, 2017). First, we modeled effects of age, education, and literacy on all cognitive domains to assess which domains were most affected by these predictors. Effects of gender on cognitive factors were tested in series of models, sequentially controlling for additional predictors that might influence the relationship between gender and cognitive function (Figure 1). Model 1 estimated regression slopes for all cognitive factors regressed simultaneously onto gender, age, country of origin, and marital status. In Model 2, education and literacy were added to the model, followed by health factors (Model 3), and additional socioeconomic factors (Model 4). Differences in the effect of covariates across latent cognitive domains were tested using the Wald chi-square test of parameter equalities. Factor mixture modeling was used to identify subgroups of participants based on cognitive performance profiles; differences between latent classes were examined using multivariate analysis of variance for continuous covariates and chi-square test for categorical covariates. Latent variable analyses were conducted in Mplus version 8 using maximum likelihood estimation (Muthén & Muthén, 2017).

Results

Gender Differences in Covariates and Raw Cognitive Measures

Relative to men, women were younger, less likely to be married, and were more likely to have been born outside of South Africa (Table 1). On average, women experienced slightly higher comorbidity burden than men, driven by higher self-reported cancer prevalence among women.

[2] Chronic health conditions were combined into a single index variable for the purpose of model simplicity. However, we also tested models where each condition was treated as a separate covariate and the results were unchanged. Cancer and stroke were based on self-report. Measured blood pressure during the laboratory visit was available for 1,619 (84%) of participants, and individuals were considered hypertensive if systolic blood pressure ≥140 and/or diastolic blood pressure ≥90. If blood pressure values were missing from the lab visit, we used the measured blood pressure from the main survey and applied the same cutoffs, or if missing, used self-reported use of antihypertensive medications. Diabetes was defined by self-reported diabetes treatment, or when available, blood glucose ≥7 mmol/L (126 mg/dL) if fasting or glucose ≥11.1 mmol/L (200 mg/dL) if not fasting. HIV status was established via dried blood spot assay.

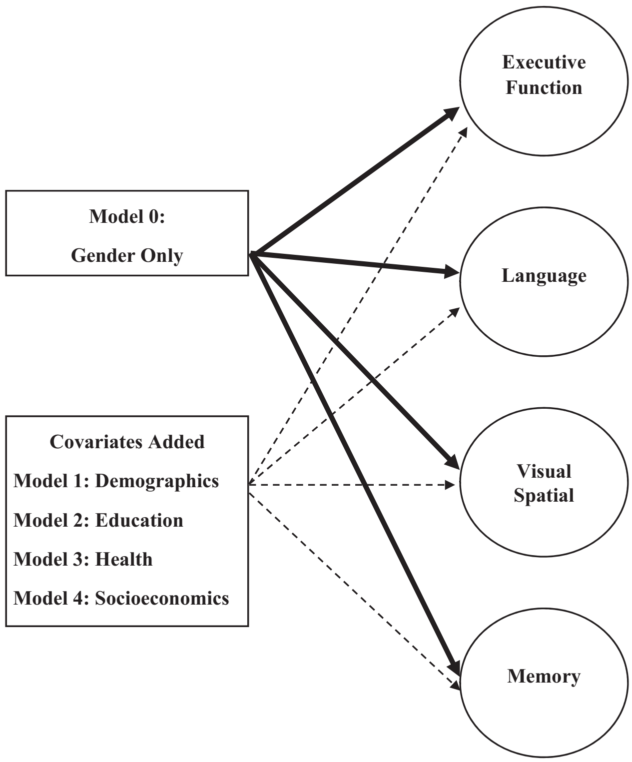

Figure 1. Schematic drawing of the Multiple Indicators Multiple Causes (MIMIC) models. Ovals represent the latent cognitive factors. The parameters of interest, that is, the pathways between gender and latent cognitive factors, are depicted in bold. Each model includes additional covariates of interest, including demographic factors (Model 1), education factors (Model 2), health factors (Model 3), and socioeconomic factors (Model 4).

Household wealth and work status were similarly distributed between men and women.

Women reported fewer years of formal education, and in particular, were significantly less likely to have ever attended school. Rates of illiteracy were higher among women, with 50% of women and 39% of men reporting inability to read and write. Given the broad age range of the sample and the possibility for policy changes across birth cohorts, we examined whether gender differences in education differed for middle-aged (40–59, n = 1,068) versus older adults (60–79, n = 870). Compared to older participants, middle-aged participants reported more years of education (M = 5.2 vs 2.2) and higher literacy rates (65% vs 41%). However, Age Group × Gender interactions were not significant for either variable, suggesting a consistent male advantage in education across the age spectrum.

Table 1 shows gender differences in raw OCS-Plus scores. Men outperformed women on a number of tasks, including orientation, picture naming, baseline trails, figure copy, and rule finding. However, women outperformed men on immediate word recall and word recognition. Overall, results from the raw OCS-Plus measures suggest a male advantage on language, executive, and visual spatial ability and a female advantage in episodic memory.

Measurement Models of the OCS-Plus

The final model derived from the EFA included four factors: language (picture naming, semantics), executive function (the three trails trials, rule finding), verbal episodic memory (immediate recall, delayed recall, delayed recognition), and visual spatial ability (figure copy, figure copy recall). Orientation, incidental memory, and the auditory attention variables loaded weakly onto multiple factors and were dropped from subsequent analysis. Although rule finding had a moderately low loading onto the executive function factor, it was retained to increase breadth of the theoretically meaningful factor. The model was tested using CFA, allowing each measure to load onto one factor. The four-factor CFA model (Figure 2) had excellent fit, CFI = 0.98, TLI = 0.96, RMSEA = .042 (95% CI = 0.036–0.049), and was consistent with the domains targeted by the scale developers.

Effects of Age and Education on Latent Cognitive Domains

Latent cognitive scores were separately examined with respect to age, education, and literacy, key factors shown to differ by gender. Significant linear and quadratic age slopes were found for each cognitive domain, as shown in Supplementary Figure 1. The steepest age gradient was observed in the visual spatial domain (β = −0.15, SE = 0.009 for age; β = −0.003, SE = 0.001 for age^2), followed by executive function (β = −0.07, SE = 0.005 for age; β = −0.001, SE = 0.001 for age^2), memory (β = −0.05 for age, SE = 0.003; β = −0.002, SE = 0.001 for age^2), and then language (β = −0.02, SE = 0.002 for age; β = −0.001, SE = 0.001 for age^2). Both years of education and self-reported literacy were significantly and independently related to performance across all cognitive domains (ps < .001). Strongest effects were observed for visual spatial (β = 0.27, SE = 0.024 for education; β = 2.19, SE = 0.22 for literacy), followed by executive function (β = 0.17, SE = 0.015; β = 0.87, SE = 0.13), then memory (β = 0.09, SE = 0.01; β = 0.34, SE = 0.08) and language (β = 0.07, SE = 0.01; β = 0.41, SE = 0.05), which did not differ. Figure 3 depicts the estimated education slopes for each standardized latent cognitive domain score.

Effects of Gender on Latent Cognitive Domains

For the main analysis of gender, we conducted sequential MIMIC models incrementally adding covariates to examine their influence on the magnitude of gender effects. Standardized coefficients are given in Table 2, where values represent differences in the latent cognitive trait in standard deviation (SD) units for every 1 SD change in a continuous predictor, or change in binary predictor from 0 to 1. Model 0 estimated the effect of gender on cognitive domains. Gender effects varied across cognitive domains, with males performing significantly better on executive function, visual-spatial ability, and language, and females performing

Table 1. Descriptive Statistics for Covariate Measures and Raw Cognitive Scores From the Oxford Cognitive Screen-Plus

Measure		Men (n = 792)		Women (n = 1,146)	
		Mean or percent	*SD*	Mean or percent	*SD*
Covariates	Range				
Age**	40–79	59.78	11.08	57.69	10.75
Married**		67.0%		42.41%	
Born in South Africa*		74.0%		69.28%	
Education (years)**	0–16	4.17	4.32	3.66	4.21
Education level					
No formal**		36.62%		43.98%	
Some primary		40.78%		36.74%	
Completed primary		22.6%		19.28%	
Literate**		61.36%		49.83%	
CESD score	0–8	1.31	1.45	1.4	1.58
Self-rated good health		71.59%		69.46%	
Comorbid conditions*	0–5	0.79	0.73	0.86	0.74
ADL limitation		5.81%		5.93%	
Highest wealth quintile		21.21%		19.28%	
Lowest wealth quintile		21.84%		20.16%	
Monthly income (in ZAR)		1,083.2	3,311.64	894.25	3,410.44
Currently working		17.30%		14.14%	
Cognitive measures	Range	Mean	*SD*	Mean	*SD*
Picture naming**	0–4	2.56	1.01	2.43	1.04
Semantics	0–4	3.29	0.77	3.29	0.78
Orientation**	0–4	3.14	1.17	2.73	1.41
Trails—circles**	0–7	3.84	2.62	3.4	2.48
Trails—squares	0–7	3.13	2.57	2.99	2.5
Trails—mixed (Switch)	0–14	4.44	4.07	4.44	3.83
Immediate word recall**	0–10	7.38	1.75	7.85	1.54
Delayed word recall	0–5	2.80	1.61	2.88	1.52
Recognition*	0–5	4.24	1.18	4.35	1.14
Incidental memory	0–4	2.68	0.96	2.73	0.91
Figure copy*	0–21	18.04	3.63	17.58	4.02
Figure copy recall	0–21	15.26	5.42	14.91	5.53
Rule finding**	0–5	1.54	1.35	1.36	1.21
Auditory attention—target	0–27	16.59	7.26	15.77	7.41
Auditory attention—distractor	0–54	32.96	16.08	34.34	16.8

Notes. CESD = Center for Epidemiologic Studies Depression Scale. ZAR = South African Rand (1 ZAR = $0.06 USD).
*$p < .05$, **$p < .01$, for differences between men and women.

significantly better on memory. Adjusting for demographic factors in Model 1 strengthened the male advantage in visual spatial and executive function. Conversely, gender effects on language and memory did not reach statistical significance in Model 1, presumably due to controlling for females' younger age (reducing the female memory advantage) and higher prevalence of non-South African born participants (reducing the male language advantage).

Controlling for education and literacy in Model 2 reduced the magnitude of the male advantage in language by 76%, executive function by 47%, and visual spatial ability by 42% compared with Model 1. Conversely, adding education and literacy increased the female advantage in the episodic memory domain by 70%. Adjusting for health indicators in Model 3 and socioeconomic variables in Model 4 did not alter the pattern or magnitude of gender effects on cognitive performance.

Model 4 revealed significant differences in the direction and magnitude of the gender coefficient across cognitive domains, $\chi^2(3) = 22.0$, $p < .001$. Overall, the female advantage in memory differed from all other cognitive domains ($ps < .001$). The male advantage was similar for executive function and visual spatial processes ($p = .12$). There was virtually no effect of gender on language performance in Model 4. Results from all comparisons are given in Supplementary Table 1.

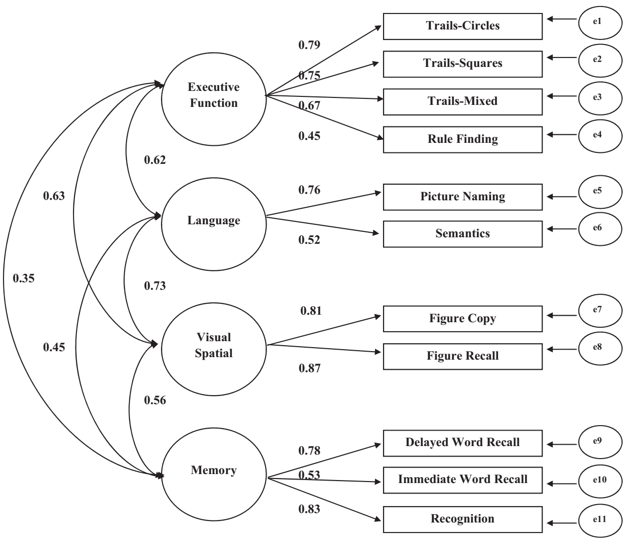

Figure 2. Confirmatory factor analysis (CFA) model of the Oxford Cognitive Screen-Plus, with factor intercorrelations and factor loadings. Standardized coefficients are shown. Model fit indices: CFI = 0.98, TLI = 0.96, RMSEA = .042 (CI = 0.036–0.049). All factor loadings and correlations are significant at $p < .001$.

Table 2 shows the proportion variance in cognitive performance explained by each model. Demographic variables explained a moderate amount of variance in each domain, ranging from 24% for memory to 38% for visual spatial abilities. Adding education variables improved the explanatory value of the model, as shown by higher R^2 values for each domain (30% for memory to 51% for visual spatial). Health and socioeconomic factors in Models 3 and 4 did not make a significant contribution beyond the effects of demographic and education factors.

Post hoc analyses stratified the fully-adjusted model by gender to explore whether specific factors had stronger effects on the cognitive performance of men versus women. Results from these analyses are given in Supplementary Table 2.

Identification and Description of Cognitive Subgroups

Results from the factor mixture model revealed three latent classes based on cognitive performance: (i) high cognitive performance (n = 1,480, 76%), (ii) mild global impairment (n = 292, 15%), and (iii) marked visual spatial impairment (n = 166, 9%). Class 1 performed best on all cognitive domains, and was characterized by sociodemographic advantage, with youngest mean age, highest levels of education and literacy, and highest proportion of individuals who were married and working. Class 2 had moderately lower cognitive scores across all domains. Individuals from this group were older and less educated compared with the high performance group, but had higher education levels compared with Class 3. The final group had marked impairment in

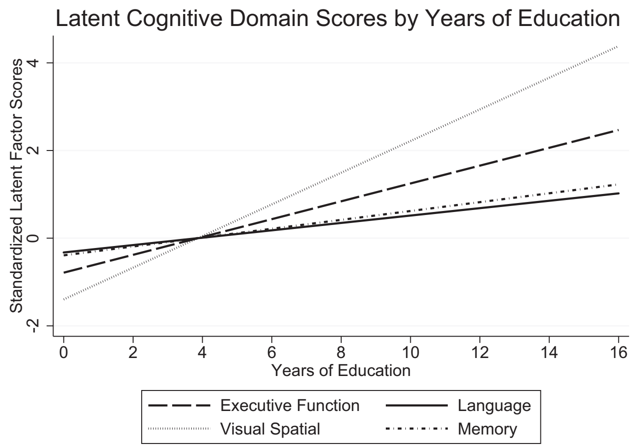

Figure 3. Estimated slopes for years of education on standardized latent cognitive factor scores.

visual spatial function, but smaller differences in the other cognitive domains relative to the high performance group. Group 3 was characterized by sociodemographic disadvantage, with the lowest levels of education and literacy and highest likelihood of being born outside of South Africa. Class 3 also had the highest percentage of woman (70%). See Supplementary Material for full description of mixture modeling process and class characteristics.

Discussion

In this rural South African cohort, men and women exhibited different strengths when approaching the same set of cognitive measures, where women outperformed on verbal episodic memory tasks despite significant disadvantage in educational attainment and literacy. Conversely, men outperformed on visual spatial and executive function tasks, even after controlling for a variety of covariates. These patterns largely cohere with research from higher-income countries reporting modest, and domain-specific gender differences in cognitive performance.

In our cohort, women were less likely to have attended school or learned to read and write, a pattern that may reflect both oppressive Apartheid-era education policies, as well as patriarchal gender role attitudes in rural South Africa (Oberhauser & Pratt, 2004). Given these conditions, it is perhaps unsurprising that education and literacy were among the most important factors in explaining gender disparities in cognitive function, reducing or eliminating gender differences in executive function, language, and visual spatial domains, while boosting the female advantage in memory. In line with these findings, studies from other low- and middle-income countries in Asia, Latin America, and Northern Africa also saw significant reductions in cognitive gender disparities after adjusting for differences in education and socioeconomic resources (Maurer, 2011; Weir et al., 2014; Yount, 2008).

Table 2. Multiple Indicators Multiple Causes (MIMIC) Models Estimating Effects of Gender and Covariates on Latent Cognitive Domains

	Executive function		Visual spatial		Memory		Language	
Model	Coeff.	*SE*	Coeff.	*SE*	Coeff.	*SE*	Coeff.	*SE*
0—Gender only								
Female	**–0.16****	**0.06**	**–0.16****	**0.06**	**0.14***	**0.05**	**–0.13***	**0.06**
Latent factor R^2	0.006	0.004	0.006	0.004	0.004	0.004	0.004	0.004
1—Add demographic factors								
Female	**–0.18****	**0.05**	**–0.21****	**0.05**	**0.09**	**0.05**	**–0.1**	**0.05**
Age	–0.39**	0.02	–0.51**	0.02	–0.43**	0.02	–0.34**	0.02
Age^2	–0.05*	0.02	–0.09**	0.02	–0.15**	0.02	–0.05*	0.02
Mozambican/other	–0.53**	0.05	–0.6**	0.05	–0.26**	0.05	–0.82**	0.05
Married	0.17**	0.05	0.18**	0.05	0.16**	0.05	0.24**	0.05
Latent factor R^2	0.24	0.02	0.38	0.02	0.25	0.02	0.29	0.02
2—Add education factors								
Female	**–0.09**	**0.05**	**–0.12***	**0.05**	**0.14****	**0.05**	**–0.02**	**0.05**
Age	–0.22**	0.03	–0.34**	0.02	–0.3**	0.03	–0.16**	0.03
Age^2	–0.09**	0.02	–0.11**	0.02	–0.18**	0.02	–0.09**	0.02
Mozambican/other	–0.2**	0.06	–0.24**	0.06	–0.01	0.06	–0.47**	0.06
Married	0.14**	0.05	0.14**	0.05	0.13**	0.05	0.19**	0.05
Education (years)	0.25**	0.03	0.21**	0.03	0.2**	0.03	0.28**	0.03
Literate	0.34**	0.06	0.55**	0.06	0.22**	0.06	0.38**	0.06
Latent factor R^2	0.33	0.02	0.51	0.02	0.3	0.02	0.41	0.03
3—Add health factors								
Female	**–0.09**	**0.05**	**–0.12***	**0.05**	**0.14****	**0.05**	**–0.02**	**0.05**
Age	–0.22**	0.03	–0.34**	0.02	–0.3**	0.03	–0.15**	0.03
Age^2	–0.08**	0.02	–0.11**	0.02	–0.18**	0.02	–0.09**	0.02
Mozambican/other	–0.2**	0.06	–0.23**	0.06	–0.01	0.06	–0.47**	0.06
Married	0.14**	0.05	0.14**	0.05	0.13**	0.05	0.19**	0.05
Education (years)	0.25**	0.03	0.21**	0.03	0.20**	0.03	0.28**	0.03
Literate	0.34**	0.06	0.55**	0.06	0.22**	0.06	0.38**	0.06
ADL limitation	–0.07	0.11	–0.17	0.1	0.05	0.11	–0.02	0.1
CESD	–0.01	0.02	0.02	0.02	–0.02	0.02	–0.03	0.02
Comorbidity index	–0.003	0.02	–0.007	0.02	–0.01	0.02	0.003	0.02
Self-rated good health	0.04	0.06	–0.08	0.05	–0.03	0.06	0.04	0.06
Latent factor R^2	0.33	0.02	0.51	0.02	0.3	0.02	0.41	0.02
4—Add socioeconomic factors								
Female	**–0.11***	**0.05**	**–0.14****	**0.05**	**0.14****	**0.05**	**–0.04**	**0.05**
Age	–0.24**	0.03	–0.36**	0.03	–0.31**	0.03	–0.17**	0.03
Age^2	–0.08**	0.02	–0.11**	0.02	–0.18**	0.02	–0.08**	0.02
Mozambican/other	–0.17**	0.06	–0.21**	0.06	0.006	0.06	–0.43**	0.06
Married	0.11*	0.05	0.13**	0.05	0.12**	0.05	0.14**	0.05
Education (years)	0.23**	0.03	0.21**	0.03	0.19**	0.04	0.23**	0.04
Literate	0.33**	0.06	0.54**	0.06	0.22**	0.06	0.37**	0.06
ADL limitation	–0.06	0.11	–0.16	0.1	0.06	0.1	–0.002	0.1
CESD	–0.005	0.02	0.02	0.02	–0.02	0.02	–0.03	0.02
Comorbidity index	–0.004	0.02	–0.006	0.02	–0.01	0.02	0.001	0.02
Self-rated good health	0.04	0.06	–0.08	0.05	–0.03	0.05	0.04	0.05
Wealth	0.06*	0.03	0.04	0.02	0.03	0.03	0.12**	0.03
Income	0.03	0.03	–0.01	0.02	0.03	0.02	–0.02	0.02
Working	0.002	0.07	–0.1	0.06	–0.003	0.07	0.11	0.07
Latent factor R^2	0.34	0.02	0.52	0.03	0.31	0.02	0.42	0.02

Notes. Standardized coefficients are shown, such that values represent change in latent cognitive domains in standard deviation units for a standard deviation change in continuous predictor, or change in binary predictor from 0 to 1. CESD = Center of Epidemiologic Studies Depression. The first row in each model is in bold to highlight the main effect of interest, gender.

*$p < .05$. **$p < .01$.

Associations between education and later-life cognitive performance is well-established (Glymour, Kawachi, Jencks, & Berkman, 2008; Stern, 2009; Zahodne et al., 2011; Zahodne, Stern, & Manly, 2015). However, most evidence supporting the relationship between education and late-life cognition has come from study samples with much higher levels of education (Langa et al., 2017). The magnitude of education–cognition relationships observed here is particularly interesting given low but varied levels of educational attainment in our cohort. These data support previous findings from the United States showing that early life education is strongly associated with later-life cognitive health, and that higher credentialing thresholds are not required to experience education-related benefits (Zahodne et al., 2015).

Several nonmutually exclusive mechanisms may contribute to the effect of education on late-life cognition. According to the cognitive reserve hypothesis, education may facilitate the development of critical cognitive and neural processes which in turn render the individual more resilient to late-life cognitive decline (Stern, 2009). Higher education may lead to better experiences throughout the lifespan, including higher-paying and more stimulating occupational opportunities, larger social networks, and increased knowledge of and access to health care (Zahodne et al., 2015). A third contributing factor may be superior task performance for higher educated participants due to greater exposure to and familiarity with the testing environment and task stimuli (Ardila, 1995). All of these factors likely contributed to the powerful effects of education in our cohort.

Consistent with previous research, older age was a strong determinant of cognitive performance. Every 11 years of age was associated with a quarter to half standard deviation drop in cognitive performance depending on the cognitive domain, which is on par with age gradients reported in other global cohort studies (McArdle, Fisher, & Kadlec, 2007; Skirbekk, Loichinger, & Weber, 2012). For example, Skirbekk and colleagues (2012) compared the age gradients of word recall and verbal fluency across cohort studies in the United States, Europe, China, India, and Mexico and reported 0.23–0.39 *SD* drop per decade in word recall, and 0.15–0.33 *SD* drop per decade in verbal fluency. In our study, the age slope was steepest in the visual spatial domain, which may also reflect age-related declines in visual acuity. Surprisingly, health and socioeconomic variables did little to explain gender patterns of cognitive performance above and beyond the effects of education and sociodemographic factors. Similar levels of overall health between men and women in our sample may be one reason why these particular factors were not influential with regard to cognitive gender patterns. Although some previous studies have reported higher rates of cardiovascular disease risk, depressive symptoms, and HIV among sub-Saharan African women versus men (Gaziano et al., 2017; Gómez-Olivé et al., 2017; Njelekela et al., 2009; Ramjee & Daniels, 2013; Tomlinson, Grimsrud, Stein, Williams, & Myer, 2009), in our study sample there were not significant gender differences in most measured health conditions. Men and women also did not differ in terms of wealth, income, or work status. It is important to note that wealth (assets) and income were measured at the household level; had these constructs been measured at the individual level we may have seen greater disparity between men and women.

Gender patterns, as well as the contribution of education and other covariates to cognitive performance, differed significantly across cognitive domains. As hypothesized, male advantages were largest in cognitive domains with the strongest education and literacy associations: visual-spatial ability and executive function. However, the observation of heightened education effects on these measures contradicts long held assumptions that nonverbal, fluid abilities are less sensitive to education effects than verbal measures. We are not the first to report stronger education and literacy effects on executive function and visual-spatial tasks (Rosselli & Ardila, 2003). Many nonverbal neuropsychological tests require skills that are honed through classroom learning and exposure to written text, including visual scanning, planning, and drawing. Despite the novel and nonverbal nature of the OCS-Plus measures, the core subtests in these domains (figure copy and trail making) required the use of a stylus to draw or connect lines on the tablet. Hence, literacy effects may in part reflect the participants' level of familiarity with a writing implement, even though the tasks did not explicitly require text reading or writing. Overall, our findings suggest that the degree to which education influences test performance is determined by the specific skills required of the test and the cultural relevance of these skills for individuals at various levels of educational attainment.

Although gender differences in visual spatial ability and executive function were reduced by nearly 50% after controlling for education and literacy, remaining gender gaps indicate that unmeasured biological and social processes further enabled divergence by gender. Unique social and cultural roles played by men and women in rural South Africa undoubtedly influence the development of specific cognitive skills. One possibility is that men developed superior visual spatial and executive skills through migration and work experiences, which were far less available to women during critical periods of early adulthood. In support of this theory, women were more likely to belong to latent Class 3, which was characterized by marked impairment in visual spatial ability, specifically. Class 3 was the only latent group that differed by gender, suggesting that overall cognitive differences between men and women may in fact be driven by a small subgroup of older women with the most pronounced sociodemographic disadvantages.

Similarly, women's superior performance on episodic memory, in spite of limited educational and occupational opportunities, speaks to the unique social roles of older women in rural South Africa. In this context, women often had to function as heads of household when men migrated for work, serving as the central figure maintaining family ties and intergenerational relationships (Harling et al., 2018; Schatz, Madhavan, & Williams, 2011). Older South African women are also much more likely to provide care for both children and grandchildren, perhaps providing additional opportunity for social stimulation. Therefore, it is highly probable that roles as kin keepers and caregivers allowed older women to develop and maintain verbal memory skills to a greater extent than their male counterparts, who were less likely to engage in these complex social dynamics during middle and older adulthood.

The language domain showed comparatively weaker gender effects overall. The gender coefficient for language was reduced virtually to zero in Model 2, suggesting that nearly all of the gender-related variance in language performance was driven by demographic factors and education disparity, including the higher prevalence of non-South African participants among women. The language domain also showed weaker effects of education and literacy than other cognitive domains. These data suggest that the type of language skills assessed in OCS-Plus (object naming and semantic organization) may be more universally relevant than other measures, allowing men, women, and individuals with various levels of formal education to develop these core skills.

Secondary analyses stratified by gender uncovered two factors that were differentially important for men versus women: marital status and wealth. Marital status had a stronger influence on the cognitive performance of older men compared with women. This aligns with previous research showing greater benefits of marriage and greater consequences of widowhood on men's physical health and subjective well-being, which has largely been attributed to their greater reliance on spouses for social support and lifestyle maintenance (Williams & Umberson, 2004; Wörn, Comijs, & Aartsen, 2020). Our data extend these findings and suggest that protective mechanisms associated with marriage also have a stronger influence on the cognitive health of older South African men. Conversely, the effect of household wealth was more pronounced for women compared with men. One possibility is that older women, who have experienced less financial autonomy then men, may be more vulnerable to perceived and actual financial limitations than their male counterparts. The exact mechanisms underlying gender differences in the effects of marital status and household wealth on cognitive function warrant further investigation.

Our findings are limited by the cross-sectional design of the study, precluding our ability to understand the temporal order of risk factors and cognitive outcomes. Future longitudinal analyses will examine trajectories of cognitive change to better understand when gender differences emerge during the life course, and whether protective mechanisms differ by sex. Our measure of literacy was based on self-report, so it is highly possible that a more objective literacy assessment would reveal different and potentially stronger effects on cognitive outcomes. The final measurement model excluded three of the original OCS-Plus measures to improve interpretability of the factors, which led to some factors having fewer predictor variables than desired. However, a strength of the study is our ability to assess multiple cognitive domains using measures with less reading and numeracy demands than many common neuropsychological tests.

Conclusions

Our findings support the concept that gender differences in older adults' cognitive function reflect a combination of biological and environmental factors, including different educational exposures and divergent social roles, and inherent sex differences in brain structures and processes. We further validate the importance of early educational opportunities in determining late-life cognitive levels across cultural contexts and highlight the importance of using culturally-appropriate and multi-dimensional cognitive outcome measures to characterize differences in cognitive function between groups.

As cognitive function is a strong determinant of autonomy in older age, understanding how education, literacy, and other related factors contribute to gender-based inequality in late-life cognitive function has profound implications for the promotion of health, productivity, and quality of life across aging populations globally. While most high-income countries have seen gender disparities in educational attainment shrink or reverse over time, such trends have taken much longer to manifest in other parts of the world, including sub-Saharan Africa (Permanyer & Boertien, 2019). As low- and middle-income countries begin to adopt more gender-equal attitudes and policies, we should expect the gender gap in cognitive performance to narrow in response.

Supplementary Material

Supplementary data are available at *The Journals of Gerontology, Series B: Psychological Sciences and Social Sciences* online.

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Ethical Approval and Consent

The study received ethical approvals from the University of the Witwatersrand Human Research Ethics Committee (M141159), the Harvard T.H. Chan School of Public Health, Office of Human Research Administration (C13-1608-02), and the Mpumalanga Provincial Research and Ethics Committee (approved: 2014/10/22). Each participant provided written informed consent (or by a proxy, when needed).

Conflict of Interest

None reported.

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