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Gender Differences and Cognition Among Older Adults

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ABSTRACT

The more replicated findings about gender difference in cognitive performance suggest female superiority on visuomotor speed and language ability and male superiority on mechanical and visuospatial tasks. Generally, group strengths found in the early school years become more established at adolescence and remain stable through adulthood. The current study tested whether the patterns established in the early years remained among 30 adult subjects. We also utilized a series of exploratory analyses to determine if observed gender differences were impacted by the covariance present between all cognitive tests. Results suggest that although the patterns established in the early years remain stable through time for males, the established patterns for females are altered with age. Our findings are compelling in supporting a male advantage on visuospatial tasks among older adults. These findings are discussed in terms of common variance between test instruments as a possible source of difference. Our finding that the gender effect tended to increase when common variance was controlled argues that this methodology may enhance the ability to detect domain specific effects.

Keywords: cognition, gender differences, aging, common variance

The analysis of gender differences in cognitive ability is a widely studied and controversial topic. The replicated findings related to performance differences suggest female superiority on visuomotor speed and language ability and male superiority on mechanical and visuospatial tasks. Generally, group strengths found in the early school years become more established at

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adolescence and remain stable through adulthood. Although sparse, recent studies have considered the course of these established differences in advanced age (65+). Of specific interest is whether or not the patterns established in the early years remain stable through time or if they are altered with age.

Female advantages in the verbal domain include word fluency, spelling, language ability and grammatical usage (Kimura, 1999) as well as verbal memory – for simple lists of unrelated words, digits, or paragraph content (Heaton, Ryan, Grant, & Matthews, 1996; Kimura, 1999; Rosser, Ensing, Glider & Lane, 1984). Additional female advantages have been found on object location memory (Eals & Silverman, 1994; McBurney, Gaulin, Bevineni, & Adams, 1997), and speed in fine motor skills (Hall & Kimura, 1995; Nicholson & Kimura, 1996). Additional female advantages may include: ability on computational tests (Chapman, 1988), visual memory for objects (Galea & Kimura, 1993; Harshman, Hampson, & Berenbaum, 1983), depth and perceptual speed (Kimura, 1999; Majeres, 1983), spelling (Kimura, 1999), wayfinding with landmarks (Williams, Barnett, & Meck, 1990), and incidental memory (McGuinness, Olson, & Chapman, 1990). McCarthy (1954) and Maccoby (1966) suggest that female superiority in verbal tasks is established around the age of 10–11, and is maintained throughout the college years (Maccoby & Jacklin, 1974).

Studies of male advantages in visual spatial ability suggested it begins around 6 to 8 years of age (Maccoby, 1966). Visuospatial ability involves the skill to draw from a model or from memory, to make patterns with objects like blocks, to reason about spatial relations among objects, and to read and follow maps. Some have suggested that although this male advantage remains until adulthood, differences may disappear in old age (Schwartz & Karp, 1967). The most consistent and reliable male advantage is found on tests of mental rotation of spatial stimuli (Peters et al., 1995; Voyer, Voyer, & Bryden, 1995). Further, male advantages have been found in problem-solving aptitude tests, targeting (Watson & Kimura, 1991), and a slight advantage on verbal intelligence (Halpern, 1992).

Reported gender differences in cognitive ability among the elderly vary depending upon methodology and measures employed. Some researchers suggest that discrepancies in performance among the sexes have disappeared altogether. Armstrong and Walker (1994) found that on formal verbal ability and verbal memory tests, males and females produced similar results. While finding gender differences in the performance of demented elderly participants, Buckwalter et al. (1996) report no significant differences in non-demented elderly on a global screening measure, tests of visuospatial organization and construction, and a semantic naming task. Corey-Bloom et al. (1996) also found there to be no gender differences in performance on their battery (global screening, verbal and visual memory tasks, category fluency, and maintaining cognitive set). Savage and Gouvier (1992) found no significant differences between the sexes on a structured verbal memory task (American Verbal Learning Test), a task that includes components that show a female advantage in younger participants.

There are other studies reporting that expected gender patterns hold fast with age. Blecker, Bolla-Wilson, Agnew and Meyers (1988) found that females retain an advantage over males in verbal memory well into their eighties. Portin, Saarijarvi, Joukamaa, and Salokangas (1995) demonstrated similar results. Others demonstrate unexpected gender differences in the later years. Although Rosseli and Ardila (1991) found a female advantage on a visual memory task, it was limited to the more highly educated females (more than 12 years of education) in the 56–60 and 61–65 year age ranges. Instead of the expected female advantage, Elias, Elias, D'Agostino, Silbershatz, and Wolf (1997) reported male superiority on a verbal memory task for paragraph content (except for the least educated males in the oldest group; education grade range 5–8; age 75–88). Elias et al. (1997) also found a female advantage on word fluency (except in the oldest and most educated males). Wiederholt, Cahn, Butters, and Salmon (1993) also found a male advantage in verbal category fluency in a sample of 54–95 year olds. Outside of that exception, in the Wiederholt study males and females performed along expected lines, females outperforming males on verbal tasks and males outperforming females on spatial tasks.

Schaie, Maitland, Willis, and Intrieri (1998) found that males retain superior spatial rotational abilities into the eighties and perform better than females in later years on the water-level task. This is consistent with a male advantage seen among older samples on Block Design (Portin et al., 1995), Trails A (Portin et al., 1995) and Trails B (Ernst, 1987). However, Robert and Tanguay (1990) suggest that the male advantage on the Rod and Frame test may not persist into old age.

The consistent variability across studies of gender differences suggests the presence of one or more extraneous variables. One possible extraneous variable is the covariance that exists among measures designed to assess over-lapping cognitive domains. The above-sited studies use of a domain-based approach may be limited in that neuropsychological assessment is not categorically specifiable into well-delineated domains. According to Dodrill (1997), poor test specificity may be revealed in the median correlations for common neuropsychological tests. For example, Dodrill asserts that while the median correlation within domain groupings on a test was .52, the median correlation between groupings was .44. From this, Dodrill extrapolates that the tests are not unambiguously domain specific because the median correlations should be notably higher for the within groupings and lower for the between groupings. Consequently, the principal assessment measures used by practitioners may not be quantifying domains to a level of specificity that accounts for the covariance among the measures.

Modeling of gender differences in cognitive domains among the elderly requires an analysis of possible covariance among the participants' item set. Covariance among cognitive measures indicates a common attribute. This common attribute among measures may obfuscate mean differences between males and females. If a cognitive domain does differ between males and females specific cognitive tests may not be equally good measures of this domain – some may be more sensitive than others in measuring the attribute and may discriminate more clearly between levels of the attribute.

The purpose of this study was to compare performance of elderly males and females on a standardized neuropsychological battery of tests. We were interested to see if the participants in the study demonstrated differences along expected gender lines established in earlier years, or if the patterns have changed with advancing years. We also utilized a series of exploratory analyses to determine if observed gender differences were impacted by the covariance present between all cognitive tests.

METHODS

Participants

Thirty community dwelling older adults (15 males and 15 females) between the ages of 65 and 92 participated in the present study. Participants consisted mainly of volunteers from the Andrus Gerontology Center at the University of Southern California and resided in the greater Los Angeles area. Participants were paid $50.00 for their participation in the study. There were no significant differences between males and females on age (males, mean = 74.8, SD=6.18; females, mean = 73.4, SD=7.46) or education (males, mean = 16.4, SD=3.1; females, mean = 14.8, SD= 2.53). Exclusion criteria included history of neurological illness, physical, or psychiatric disorder that might impair performance. Participants were also excluded if they score less than 30 on the Telephone Interview of Cognitive Status-modified (Welsh, Breitner, & Magruder-Habib, 1993).

Procedures

Informed consent was obtained. Also, participants completed a number of surveys sent to their homes that included a basic demographic questionnaire and a handedness inventory.

Along with the neuropsychological battery, tests of auditory and visual acuity were administered. The neuropsychological battery included a diverse set of assessment tools, widely utilized and standardized for use with older adults. The *California Verbal Learning Test (CVLT)* was employed to assess verbal learning and memory. Primary attentional capacity and mental tracking, within the verbal domain, was assessed with the WAIS-III *Digit Span*

Forwards and Digit Span Backwards subtests. In the visual domain, visuospatial skills were assessed with *Judgment of Line Orientation (JLO). Visual Reproduction II* (WMS-III Subtest) was utilized to assess visual learning and memory. Primary attentional capacity and mental tracking, within the visual domain, was assessed with *Trailmaking Tests A and B*. Due to the potential influence of emotional status on psychological and neuropsychological test performance, emotional status was assessed through use of the *Symptom Checklist-90 (SCL-90).* This test is composed of 90 items, which assess for a number of major symptoms of psychological disturbance.

Data Analysis

Given the similarity of males and females on age and education, no correction for these variables was employed. To assess which patterns of performance were retained for male and female participants, our data analysis was completed in two stages. In the first stage, the reference distribution is performance of each gender group. *t*-tests for independent samples were used to evaluate the significance of gender differences. In the second stage, common variance among all tests is controlled. To remove the common variance among measures, we extracted the shared variance between all tests. To remove the common variance among measures, we first calculated eigenvalues via least squares procedures. This eigenvalue analysis was performed using a principal component analysis module. It is important to note that our goal was explicitly not to perform a typical principal component analysis, in which data reduction is the goal. Instead, we used the principal component analysis module because it allowed us to extract one unrotated factor that accounted for the largest possible portion of matrix variance. Hence, we extracted the first principal component only. This unrotated factor reflected the shared variance between all tests. After extraction, scores on the factor were saved for use in an extension analysis. We then calculated semi-partial correlations between a dummy coded variable reflecting gender and all neuropsychological tests controlling for the shared variance factor. These semipartial correlations would be expected to control for the effects of overlap among measures of cognitive domains, thus providing an analysis of gender differences independent of common variance between measures.

RESULTS

Descriptive statistics for all tests are shown in Table 1. The corrected and uncorrected correlations are represented in Table 2. The shared variance factor for each test is shown in Table 3. When analyzing uncorrected correlations, gender showed significant associations with the Judgment of Line Orientation ($r = -.69$) and Mental Rotation Task ($r = -.53$). After controlling for the shared variance component gender showed significant associations

TABLE 1. Descriptive Statistics for Neuropsychological Tests

				Mean		*SD*		
Test	*Mean*	*SD*	Range	Male	Female	Male	Female	*t*
Judgment of Line Orientation								
Raw Score	24.20	5.40	10–30	27.87	20.53	2.61	4.98	5.05
								.00
Digit Span Forward	7.93	1.87	5.0–12	7.73	8.13	1.79	2.00	–0.58
								.57
Digit Span Backward	6.90	2.12	3.0–12	7.00	6.80	2.30	2.01	0.25
								.80
Visual Reproduction II								
Raw Score	46.43	24.15	0.0–87	53.87	39.00	23.56	23.13	1.74
								.09
California Verbal Learning Test								
List A – Long Delay	8.10	3.80	0.0–15	7.60	8.60	3.79	3.87	–0.71
Free Recall								.48
Reaction Time	0.44	0.09	0.3–00.78	0.41	0.47	0.06	0.11	–1.73
								.10
Trails A	39.90	18.50	17–102	39.27	40.53	22.40	14.36	–0.18
								.86
Trails B	123.43	77.62	46–402	133	113	91.69	62.06	0.71
								.48
Mental Rotation Task	5.8	4.2	1–18	4.9	1.5	8	3.6	3.3
								.00

Note. For all analyses, *N* = 30.

with the Judgment of Line Orientation (r = –.73), Digit Span Forward (r = –.39); Trails B (r = –.51), and Mental Rotation Task (r = –.48). In all instances males exhibited better performance.

DISCUSSION

The results suggest that although the patterns established in the early years remain stable through time for males, the established patterns for females are altered with age. Results from the uncorrected analysis revealed no significant differences between males and females on measures assessing verbal domains. These results comport well with many of the reported gender differences in verbal ability among the elderly – that on formal verbal ability and verbal memory tests, males and females produced similar results (Armstrong and Walker, 1994; Buckwalter et al., 1996; Corey-Bloom et al., 1996; Savage and Gouvier, 1992). Contrariwise, these results run contra to those found in two studies reporting older females retaining an advantage over males in verbal memory (Blecker et al., 1988; Portin et al., 1995). In this study the pattern of non-verbal superiority established in the males'

TABLE 2. Regressions Comparing Normal Regression and Regression Controlling for Shared Variance

Test	Normal regression	Control shared variance
Judgment of Line Orientation		
Raw Score	−.69	−.73
	.00	.00
Digit Span Forward	.10	.39
	ns	.03
Digit Span Backward	−.05	.26
	ns	ns
Visual Reproduction II		
Raw Score	−.31	−.15
	ns	ns
CVLT List A – Long Delay		
Free Recall	.13	.27
	ns	ns
Reaction Time	.31	.18
	ns	ns
Trails A	.04	−.19
	ns	ns
Trails B	−.13	−.51
	ns	.00
Mental Rotation Task	−.53	−.48
	.00	.00

Note. For all analyses, $N = 30$.

TABLE 3. Shared Variance Factor

Test	Shared variance
Judgment of Line Orientation	
Raw Score	0.73
Digit Span Forward	0.62
Digit Span Backward	0.73
Visual Reproduction II	
Raw Score	0.71
CVLT List A – Long Delay	
Free Recall	0.36
Reaction Time	−0.54
Trails A	−0.60
Trails B	−0.71
Mental Rotation Task	0.72

Note. For all analyses, $N = 30$.

early years remained stable through time. Results from the uncorrected analysis revealed significant differences between males and females on measures assessing non-verbal domains. These results replicate findings in studies reporting males retaining superior spatial rotational abilities in general (Schaie et al., 1998). However, these results are contra those found in studies reporting no significant differences in non-demented elderly on global screening measures that often include a visuospatial component, and tests of visuospatial organization and construction (Buckwalter et al., 1996; Corey-Bloom et al.,1996). Further, although current results replicated findings in studies reporting males retaining superior spatial rotational abilities in general, it did not do so on studies finding male superiority for completing Trails A (Portin et al., 1995) and Trails B (Ernst, 1987). This lack of replication of certain non-verbal domains may be due to the obfuscating influence of common variance among the measures (discussed below).

Since reported gender differences in cognitive ability among the elderly vary depending upon methodology and measures employed, we utilized a series of exploratory analyses to determine if observed gender differences were explained by the common variance among tests. Our results revealed that control of the factor that accounted for the largest possible portion of matrix variance between all tests resulted in significant associations with the Judgment of Line Orientation, Digit Span Forward, Trails B, and Mental Rotation. While significant differences in Judgment of Line Orientation and Mental Rotation Task had already been found in the baseline analysis, it was interesting to find that controlling for the common variance resulted in significant results for Digit Span Forward and Trails B.

Although Digit Span Forward showed significant results, Digit Span Backward did not. It should be noted that when controlling for the common variance, the effect size for Digit Span Backward showed an increase comparable to that seen with Digit Span Forwards. Thus, the failure to find significance may relate to the relatively low power of the study.

The removal of the common variance allowed us to replicate the gender differences found in Trails B (Ernst, 1987) and provides greater consistency in our general finding that males' visuospatial superiority is maintained into advanced age. The Trails B test is a good general indicator of gender difference in aging populations because its cognitive demands include visual abilities (scanning, visual-spatial and visual-motor coordination) adequate enough to maintain cognitive set during the alternating pattern of numbers and letters (Bradford, 1992). There are several factors that make Trails B more demanding: a) the Trails B test has at least one or more items in the path of the trail, which creates visual interference; b) Trails B requires more complex cognitive processes involved in alternating between number and letter; c) Trails B requires the integration of two independent series; and d) Trails B entails the ability to learn an organizing principle and apply it systematically (Gaudino, Mark, & Nancy, 1995). The working memory needed to complete the task alternation aspect of Trails B, in addition to our near significant findings for Digit Span Backward may indicate that aspects of executive/frontal lobe function may be gender specific in the elderly.

In summary, the results suggest that although the patterns established in the early years remain stable through time for males, the established patterns for females are altered with age. The methodology we employed that removes common variance does not address the inconsistency between our null findings between males and females on verbal tasks and those studies that have reported that elderly females continue to hold an advantage. This suggests that our study may be underpowered to detect such differences or that some additional extraneous variable (e.g., use of hormone therapy) remains uncontrolled.

Our small sample size may be a problem in that the data feature space dimensionality is large compared with the number of available participants. In order to construct a stable covariance matrix in the data feature space, an estimate of the matrix parameters (covariates) from the data set is needed. Since our sample size is small, the sample estimate of the covariance matrix may become unstable as data dimensionality increases. As a result, our small sample size may result in a misrepresentation of the data feature space. Although estimates on small data sets tend to be biased and may have a large variance, the current analyses aimed at "removal" of the common variance among measures through an extraction of the shared variance between all tests. Our goal was not the development of a factor model in which the factors are based on a reduced correlation matrix. Instead, we desired a single factor that represented all of the common variance among the neuropsychological tests. This goal is far removed from the goal of factor analysis. We do not attempt to reproduce the entire covariance matrix rather just one dimension of the matrix–the shared variance. Focusing on this single dimension may mitigate the instability issues inherent in small samples. We argue this approach warrants further consideration as a method of identifying independent domains of functioning.

We used this shared variance factor to calculate semi-partial correlations between a dummy coded variable reflecting gender and all neuropsychological tests controlling for the shared variance factor. These semipartial correlations provide a novel method to control for the effects of overlap among measures of cognitive domains, thus providing an analysis of gender differences independent of common variance between measures.

Although the problem of disparate results in studies of gender effects and lateralization may still be due to some unidentified variable, that variable may not be the covariance that exists among measures designed to assess overlapping cognitive domains. Instead, reported gender differences in cognitive ability among the elderly may be due to other factors. One such factor is the level of estrogens in female participants. Hence, future research should consider hormonal fluctuation to aid in the clarification of data patterns in experiments studying the interaction of lateralization, sex, and hormones.

In summary, our findings are compelling in support of a male advantage on visuospatial tasks among older adults. We not only replicate those studies that have found such a difference, we rule out common variance between test instruments as a possible source of difference. Our finding that the gender effect tended to increase when common variance was controlled argues that this methodology may enhance the ability to detect domain specific effects.

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