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Sex differences in processing speed: Developmental effects in males and females

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Abstract

The purpose of this study was to compare the cognitive abilities and selected achievement performance of females and males across the lifespan on standardization samples of broad cognitive abilities in 1987 participants (1102 females, 885 males) from the WJ III, 4253 participants (2014 males, 2239 females) from the WJ-R, and 4225 participants (1964 males and 2261 females) from the WJ-77. Preschool through adult cohorts were included in the analyses. The results indicated that males scored significantly lower on estimates of *Gs* (processing speed) in all three normative samples, with the largest difference evident in adolescent subgroups. A secondary finding was significantly higher scores for males on estimates of comprehension knowledge (*Gc*) in all three samples. Follow-up analyses of the achievement tests also indicated lower performance for males on speeded tests such as reading fluency and writing fluency. There was a high degree of concordance across tests and no sex difference was observed in overall estimates of general intellectual ability (GIA) on the WJ III. The educational implications of these findings are discussed with an emphasis on the adolescent (high school) cohort.

Although there has long been an interest in sex differences in cognitive abilities (Jarvik, 1975; and see the review in Jensen, 1998) and although a number of different cognitive factors have been suggested as correlates to this sex difference, there have been relatively little data exploring sex differences across development from preschool into elderly adulthood using comprehensive measures of cognitive abilities and related achievement areas. Such differences are of interest both from a theoretical perspective towards understanding different and convergent neuropsychological development in males and females and from an applied perspective as any consistent developmental differences in males and females may have important performance ramifications. There appears to be consensus for the view that males and females are not different in terms of general intellectual ability (GIA) (e.g., Jarvik, 1975; Jensen, 1998), but differences can be evident within various broad and narrow abilities that contribute to GIA (Baron-Cohen, 2003; Christen, 1991; Jarvik, 1975; Jensen, 1998). In this context, GIA is defined as general intelligence (*g*) scores representing the first principal component obtained from a principal component analysis (see Jensen, 1998). In contrast to other intelligence batteries that utilize the arithmetic mean of the subtest scores to produce a "full-scale IQ," GIA scores represent the best-weighted combination of

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scores that account for the largest portion of variance in a collection of tests. The mean of the GIA standard score scale is 100 and the standard deviation is 15.

From a theoretical viewpoint, there is quite a number of sex differences reported in the literature examining neurological development in nonhuman animals, including an examination of the effects of male and female hormones on brain development (Collaer & Hines, 1995; Geschwind & Galaburda, 1987; McManus & Bryden, 1991). There have also been a number of results suggesting differential development of cortical asymmetry in males and females including right and left hemisphere rates of growth (Lutchmaya, Baron-Cohen & Raggart, 2002; Shaywitz et al., 1995), differences in the size and neural density of the corpus callosum (see the review in Dreisen & Raz, 1995), and differences in the amygdala, which has numerous testosterone receptor cells (Meany & McEwen, 1986; Rasio-Filho, Londero, & Achival, 1999; Stefanova, 1998; Vinader-Caerolis, Collado, Segovia, & Guillamon, 2000). Additional neurological differences in males and females include prefrontal cortex, superior temporal sulcus, and perhaps the planum parietale, hippocampus, and the hypothalamus (see the review in Baron-Cohen, 2003). These neurological differences are hypothesized to relate to various behavioral differences in males and females (e.g., aggression), but whether these cortical differences have ramifications for specific cognitive abilities and related achievement areas is unclear.

The Cattell–Horn–Carroll (CHC) theory of cognitive abilities provides a substantive basis for investigating the relationship between various aspects of cognitive abilities and potential sex differences. CHC theory is the integration (McGrew, 1997) of Cattell and Horn's *Gf–Gc* theory (Horn, 1965, 1988, 1991; Horn & Noll, 1987) and Carroll's three-stratum theory (Carroll, 1993, 1998). CHC theory, as operationalized, consists of nine broad cognitive abilities including three areas of acquired knowledge (comprehension-knowledge, quantitative, and reading–writing). These abilities are listed and described in Table 1. The identification of these broad abilities, or factors, has been primarily through the application of exploratory and confirmatory factor analysis procedures to large samples of subjects that have been administered a variety of intellectual and achievement tests. This structure lends itself to comprehensive exploration of sex differences in cognitive abilities.

One can speculate that any observed sex differences in cognitive ability could potentially also relate to reported sex differences in the achievement areas of math, reading, writing, and verbal skills (see Christen, 1991 for a review). For example, Benbow and Stanley (1980) reported a higher proportion of males in a high math achievement subgroup. Conversely, females score higher, on average, than males on tests of reading achievement (Willingham & Cole, 1997). The purpose of this exploratory study was to address the question of sex differences in cognitive abilities by comparing females and males using normative samples from the *Woodcock-Johnson* (WJ) series of cognitive and achievement batteries (WJ-77, WJ-R, WJ III) in preschool through elderly adult cohorts. We hypothesized that this comprehensive approach, using relatively large cohorts across three decades may yield useful information on sex differences in broad cognitive abilities. In addition,

Table 1
Nine CHC broad abilities

Broad ability	Acronym	Description
Stores of Acquired Knowledge		
Comprehension Knowledge	*Gc*	Breadth and depth of knowledge including verbal communication, information, and reasoning when using previously learned procedures.
Quantitative Ability	*Gq*	Ability to comprehend quantitative concepts and relationships, the facility to manipulate numerical Symbols.
Reading–Writing	*Grw*	An ability associated with both reading and writing, probably including basic reading and writing skills and the skills required for comprehension/expression.
Thinking Abilities		
Long-Term Retrieval	*Glr*	Ability to efficiently store information and retrieve it later, often through association.
Visual-Spatial Thinking	*Gv*	Spatial orientation and the ability to analyze and synthesize visual stimuli. The ability to hold and manipulate mental images.
Auditory Processing	*Ga*	Ability to discriminate, analyze, and synthesize auditory stimuli. Includes phonological awareness.
Fluid Reasoning	*Gf*	Ability to reason, form concepts, and solve problems that often involve unfamiliar information or procedures. Manifested in the reorganization, transformation, and extrapolation of information.
Cognitive Efficiency		
Processing Speed	*Gs*	Ability to rapidly perform automatic or simple cognitive tasks.
Short-Term Memory	*Gsm*	Ability to hold information in immediate awareness and use it within a few seconds. Includes working memory.

these instruments also include measures of acquired knowledge, so that the implications on achievement for any sex differences in intellectual ability could also be examined.

1. Method

1.1. Description of data sets

Three sets of data, each separated by 10–12 years, were available for use in this study. These data were drawn from the standardization studies for the three editions of the *Woodcock-Johnson* (WJ) series of cognitive and achievement batteries (WJ-77, WJ-R, WJ III). The WJ III (Woodcock, McGrew, & Mather, 2001) served as the principal data base whereas the WJ-77 (Woodcock & Johnson, 1977) and WJ-R (Woodcock & Johnson, 1989) provided replication cohorts from previous decades (1977 and 1989, respectively). The WJ batteries are designed to measure a comprehensive set of intellectual and achievement abilities across a wide age range. The sample underlying the standardization of each edition was carefully selected to be proportionately representative of the US population at that time in respect to several geographic and social factors.

The norming data for each of the three editions were gathered in a similar fashion. The goal of the stratified sampling design was to identify and select a sample that approximated the distribution of the US population along several community and subject variables. The tests were individually administered by well-trained and closely supervised research assistants. Note that the mean standard score for all these tests is 100 with a standard deviation of 15, which permits some degree of comparison between the three versions of the WJ. Throughout developmental work on the three editions, attention was paid to the possibility of bias and sensitivity issues. Item difficulty calibrations were conducted and compare for different groups. A special study during development of the WJ III focused on tests from the domains most likely to be biased because of language and achievement influences (McGrew & Woodcock, 2001). Comparisons of interest were male/female, white/non-white, and Hispanic/non-Hispanic. Only four items for the Hispanic/non-Hispanic comparison and one item for the white/non-white met criteria for both practical and statistical significance. No items for the male/female comparison were significant.

Finally, several exploratory and confirmatory factor analysis studies have been completed on the WJ-R and WJ III norming data (McGrew, Werder, & Woodcock, 1991; McGrew & Woodcock, 2001). For example, a review of the fit statistics for the major WJ III factor study indicates that the CHC model is the most plausible explanation for the standardization data. The comparisons to alternative models indicate that simpler models of intelligence, either those based on the hypothesized truncated CHC organizational structures (like those in the KAIT, SIB-IV, and WAIS-III) or on alternative models of intelligence (the PASS model), are less plausible for describing the relationships among the abilities measured by the WJ III.

1.2. Participant characteristics

The WJ III data included 8818 subjects ranging in age from 2 to over 90 years. The subjects were drawn from over 100 geographically diverse US communities and the sample is proportionately representative of the US population by age in respect to location, size of community, sex, race, Hispanic origin, and parental education. A subset of 1987 subjects (1102 females, 885 males), age 5 through 79 years was selected on the basis of completeness of data (these participants completed all tests of cognitive abilities and achievement) from the WJ III standardization sample to estimate general intellectual ability (GIA) and achievement.

The WJ-R data included in this study consists of 4253 subjects (2014 males, 2239 females); age 5–79 years, drawn from the standardization sample for the *Woodcock-Johnson Revised* (WJ-R) cognitive and achievement batteries. As with the WJ III, this sample included individuals who have taken both the cognitive and the achievement batteries. The total WJ-R standardization sample included 6359 subjects, age 2 to over 90 years, and is proportionately representative of the US population at that time by age with respect to various geographic and social factors.

Because there were separate WJ III and WJ-R norms generated for college students, these were separated in the analyses herein as well. A total of 262 college students (154 females and 98 males) were included in the WJ III sample and 165 college students (106 females and 56 males) were included in the WJ-R sample. Estimates of broad cognitive abilities and narrow abilities were generated for the college students and these were tested for sex differences.

The WJ-77 data were drawn from the standardization sample and includes preschool, elementary, middle school, high school and adult cohorts. The total WJ-77 standardization sample included 4732 subjects, age 3 to over 65, from 49 communities widely distributed throughout the United States. The standardization sample was proportionately representative of the US population at that time by age in respect to various geographic and social factors. A total of 4225 participants, including 1964 males and 2261 females from the WJ-77 sample were included in the analyses. College students were not part of the WJ-77 sample.

As noted in the introduction, the CHC theory of cognitive abilities is useful for conceptualizing the variety of skills that contribute to general intellectual ability and achievement. The WJ-R and WJ III cognitive batteries measure each of seven CHC broad abilities (*Gc, Glr, Gv, Ga, Gf, Gs, Gsm*) by two or more tests. Two other broad CHC abilities (*Gq, Grw*) are measured by several tests as part of the companion achievement batteries. Eight broad CHC abilities are measured by at least one test in the 1977 WJ. The WJ-77 does not include a measure of visual-spatial thinking (*Gv*).

The tests are carefully engineered to ensure high technical quality. Test development, item calibration, and scaling were facilitated through use of the Rasch single-parameter logistic test model (Rasch, 1960; Woodcock, 1999; Wright & Stone, 1979). Table 2 lists the individual tests from the three WJ batteries that provided data for analysis in these studies. Test names vary slightly from one edition of the WJ batteries to

Table 2
Tests Used in the WJ III, WJ-R, and WJ

Test	Full Scale Intelligence Clusters			Description
	WJ III	WJ-R	WJ	
	GIA (Ext)	BCA (Ext)	BCA	
Verbal Comprehension *Gc*	X			Identifying objects; knowledge of antonyms and synonyms; completing verbal analogies
General Information *Gc*	X			Identifying where objects are found and what people typically do with an object
Picture Vocabulary *Gc*		X	X	Identifying objects
Oral Vocabulary *Gc*		X	X	Knowledge of antonyms and synonyms
Analogies *Gc*			X	Completing verbal analogies
Academic Knowledge *Gc*	X	X	X	Responding to questions about science, social studies, and humanities
Vis-Aud Learning *Glr*	X	X	X	Learning and recalling pictographic representations of words
Retrieval Fluency *Glr*	X			Naming as many examples as possible from a given category
Memory for Names *Glr*		X		Learning and recalling names
Spatial Relations *Gv* (WJ-R, WJ III)	X	X		Identifying the subset of pieces needed to form a complete shape
Picture Recognition *Gv*	X	X		Identifying a subset of previously presented pictures within a field of distracting pictures
Visual Closure *Gv*		X		Identifying an object from an incomplete or masked visual representation
Sound Blending *Ga*	X	X	X	Synthesizing language sounds (phonemes)
Auditory Attention *Ga*	X			Identifying auditorily-presented words amid increasingly intense background noise
Incomplete Words *Ga*		X		Identifying words with missing phonemes
Concept Formation *Gf*	X	X	X	Identifying, categorizing, and determining rules
Analysis-Synthesis *Gf*	X	X	X	Analyzing puzzles (using symbolic formulations) to determine missing components
Visual Matching *Gs*	X	X	X	Rapidly locating and circling identical numbers from a defined set of numbers
Decision Speed *Gs*	X			Locating and circling two pictures most similar conceptually in a row
Rapid Picture Naming *Gs*	X			Recognizing objects, then retrieving and articulating their names rapidly
Cross Out *Gs*		X		Rapidly locating and marking identical pictures from a defined set of pictures
Spatial Relations (WJ) *Gs*			X	Rapidly identifying the subset of pieces needed to form a simple shape
Numbers Reversed *Gsm*	X		X	Holding a span of numbers in immediate awareness while reversing the sequence
Memory for Words *Gsm*	X	X		Repeating a list of unrelated words in correct sequence
Memory for Sentences *Gsm*		X	X	Repeating words or phrases and sentences in correct sequence
Reading Fluency *Grw*	X			Reading printed statements rapidly and responding true or false (Yes or No)
Writing Fluency *Grw*	X	X		Formulating and writing simple sentences rapidly
Math Fluency *Gq*	X			Adding, subtracting, and multiplying rapidly
Quantitative Concepts *Gq*			X	Identifying math terms and formulae; Identifying number patterns

another and these variations are identified in Table 2. Note that the Spatial Relations test in the WJ-77 is a speeded test (*Gs*) whereas the Spatial Relation tests in the WJ-R and WJ III are not speeded, and thus are measures of visual-spatial thinking (*Gv*).

1.3. Overview of analyses

A series of analyses of variance were completed to test for sex differences in GIA and in each of the broad abilities included in the WJ III, WJ-R and WJ-77. If a difference was observed, a follow-up analysis was completed on the narrow abilities contributing this significant difference. Because the large sample size yields high power, significant differences are also present in *d* values to allow for estimating the strength of any observed mean difference. Additionally, the homogeneity of variance assumption was evaluated for the general ANOVA for the WJ III, WJ-R and WJ-77 analyses using an F_{max} statistic. These indicated that no variances tested violated this assumption.

2. Results

The WJ III analyses were completed using standard scores. The analysis was designed to provide a survey of the WJ III to test for sex differences across all broad intellectual abilities and for math, reading and writing achievement. The broad abilities include General Intellectual Ability (GIA), and the factors for Verbal Ability (*Gc*), Long-Term Retrieval (*Glr*), Visual-Spatial Thinking (*Gv*), Auditory Processing (*Ga*), Fluid Reasoning (*Gf*), Processing Speed (*Gs*), and Short-Term Memory (*Gsm*). In addition, the overall Reading, Math, Writing, and Academic Knowledge scores were compared. These abilities were compared at seven age levels: 5–6 year olds, 7–9 year olds, 10–13 year olds, 14–18 year olds, 19–34 year olds, 35–49 year olds and 50–79 year olds. These levels roughly correspond to kindergarten, elementary, middle school, and high school cohorts, and young adult, middle age and senior adult cohorts. None of these participants were actively enrolled in college. An additional group, age 19–34 and actively attending college, is identified as a college sample. The means and standard deviations for the standard score data are provided in Table 3. The results for General Intellectual Ability (GIA) will be presented first. These will be followed by the results for Processing Speed (*Gs*) and Verbal Abilities (*Gc*). Finally, the results for the remaining broad abilities are presented.

2.1. General intellectual ability

The results of analyses of variance for standard scores using sex as a dummy coded blocking variable indicated no significant difference for General Intellectual Ability (GIA), $F(1, 1721)=0.01$, $p>0.50$. Males and females displayed relatively similar mean general abilities pooled across the age ranges studied (M for females $=104.4$, M for males $=103.9$). There was a significant difference across age groups, $F(6, 1721)=9.54$, $p<0.0001$. Higher scores drove the age group difference in the adult cohorts as compared to the estimates of GIA in the child and adolescent groups. The sex by age group interaction was not significant, $F(6, 1721)=1.98$, $p>0.05$. Similar to the general sample, there was no main effect for age in the college sample, $F(1, 250)=0.61$, $p>0.50$. The lack of main effect for sex is an important result as the highly similar means for GIA suggest that the overall cognitive abilities of females and males were not different in the sample. Any subsequent differences in broad abilities can be interpreted in light of this important control for general intellectual ability. It is important to bear in mind that when the results from broad abilities, speeded achievement, and selected narrow abilities are presented, the overall estimate of GIA for males and females was not different: Indeed, the mean standard scores were remarkably similar in females and males.

2.2. Processing speed

In contrast to overall GIA and most of the broad abilities, there was a highly significant sex difference in Processing Speed (*Gs*), $F(1, 1721)=24.73$, $p<0.0001$, with females scoring more than eight standard score points higher than males overall in the adolescent samples (female $M=105.5$, and male $M=97.4$) and more than five standard score points difference in the entire sample (pooled $M=106.2$ for females as compared to a pooled $M=100.9$ for males, $d=0.378$). There was also a significant main effect for age, $F(6, 1721)=11.10$, $p<0.001$ and a significant sex by age interaction, $F(6, 1721)=2.32$, $p<0.05$. The college students displayed a mean difference of 3.1 standard score units, which was not significant at the 0.05 level, $F(1, 250)=3.14$, $p>0.05$.

For age effects in the samples without college students, the kindergarteners and elementary school children had higher mean standard scores than the middle and high school students and the adult cohorts were higher than all child and adolescent cohorts. The kindergartener and elementary school cohorts were not

Table 3
WJ III (2001): Male–female standard score by age level

Variable		Age											
		5–6			7–9			10–13			14–18		
		Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS
	n:	53	44		156	191		224	239		198	216	
General Intellectual Ability	*M*:	105.0	106.5	−1.5	103.8	103.6	0.3	102.5	100.7	1.8	101.3	104.3	−3.0
	SD:	13.8	11.9		12.8	14.0		14.5	14.7		15.6	15.3	
Broad CHC Abilities													
Verbal Ability (*Gc*)	*M*:	101.6	102.2	−0.6	103.4	100.7	2.7	104.2	100.2	4.0	103.3	102.4	0.9
	SD:	10.4	14.0		12.9	14.7		14.4	14.9		16.5	14.9	
Long-Term Retrieval (*Glr*)	*M*:	107.9	110.1	−2.2	105.7	104.9	0.8	100.1	99.5	0.6	100.9	103.6	−2.7
	SD:	12.3	12.3		14.2	15.4		13.4	13.2		13.5	14.1	
Visual-Spatial Thinking (*Gv*)	*M*:	105.8	105.5	0.3	100.4	101.6	−1.2	101.2	100.3	0.9	102.4	105.9	−3.5
	SD:	13.2	11.9		13.5	13.6		13.6	14.5		15.7	15.3	
Auditory Processing (*Ga*)	*M*:	109.2	107.2	2.0	106.4	103.7	2.7	100.4	101.0	−0.6	100.3	102.8	−2.5
	SD:	14.9	14.0		14.0	12.6		14.4	15.1		15.1	14.9	
Fluid Reasoning (*Gf*)	*M*:	106.2	105.2	1.0	100.9	102.3	−1.4	102.4	100.0	2.4	100.1	102.9	−2.8
	SD:	15.4	15.1		13.0	13.3		14.4	14.7		15.5	15.1	
Processing Speed (*Gs*)	*M*:	101.8	105.5	−3.7	102.0	104.9	−2.9	97.5	103.2	−5.7	97.4	105.5	−8.1
	SD:	14.4	11.0		13.8	13.2		14.3	14.1		14.0	15.3	
Short-Term Memory (*Gsm*)	*M*:	104.6	106.8	−2.1	102.6	101.5	1.1	103.3	100.0	3.2	102.5	103.0	−0.6
	SD:	15.4	14.0		14.1	13.9		14.9	14.0		15.9	14.2	
Achievement													
Reading (*Grw*)	*M*:	106.4	110.2	−3.8	103.2	104.9	−1.6	102.4	102.6	−0.2	101.1	103.3	−2.2
	SD:	13.6	14.1		12.8	12.4		12.4	12.2		14.8	13.5	
Math (*Gq*)	*M*:	105.6	107.5	−1.9	105.3	106.2	−0.9	104.8	102.6	2.2	99.0	100.8	−1.9
	SD:	12.8	11.4		12.0	11.6		11.6	12.7		14.4	13.6	
Writing (*Grw*)	*M*:	107.1	112.8	−5.7	102.6	105.9	−3.3	99.6	102.6	−3.0	98.9	103.6	−4.7
	SD:	15.5	16.3		10.7	10.3		12.0	11.1		13.6	13.4	
Academic Knowledge (*Gc*)	*M*:	103.2	107.3	−4.1	103.8	99.5	4.2	103.5	98.7	4.9	103.2	103.8	−0.6
	SD:	10.8	13.9		11.9	12.5		13.8	14.5		17.2	14.6	

Variable		Age											
		19–34			35–49			50–79			College[a]		
		Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS
	n:	50	85		66	87		40	86		98	154	
General Intellectual Ability	*M*:	106.1	102.8	3.3	107.1	110.3	−3.1	111.6	109.0	2.6	105.4	106.0	−0.6
	SD:	11.1	13.1		12.9	11.3		11.9	13.1		12.3	11.4	
Broad CHC Abilities													
Verbal Ability (*Gc*)	*M*:	106.5	101.9	4.6	107.7	108.2	−0.5	116.4	109.7	6.8	105.4	104.5	0.9
	SD:	11.2	12.0		10.2	10.7		11.2	12.6		12.2	10.5	
Long-Term Retrieval (*Glr*)	*M*:	107.0	106.3	0.7	106.0	108.8	−2.8	112.7	111.6	1.2	108.2	109.0	−0.8
	SD:	12.8	13.7		11.0	11.5		11.0	11.7		13.1	13.6	
Visual-Spatial Thinking (*Gv*)	*M*:	103.9	105.8	−1.9	103.7	106.6	−2.8	108.4	108.7	−0.3	105.6	106.1	−0.4
	SD:	12.9	14.2		13.4	13.5		11.4	13.4		13.8	14.3	
Auditory Processing (*Ga*)	*M*:	105.9	106.9	−1.0	102.9	108.6	−5.7	107.0	106.9	0.1	107.4	107.8	−0.4
	SD:	12.2	13.7		14.1	11.5		12.1	11.6		13.5	13.0	
Fluid Reasoning (*Gf*)	*M*:	106.0	101.6	4.4	105.5	106.7	−1.3	110.2	106.6	3.6	103.6	104.3	−0.8
	SD:	10.7	13.1		11.9	9.3		13.3	11.8		11.9	11.2	
Processing Speed (*Gs*)	*M*:	107.8	108.0	−0.2	103.7	110.3	−6.7	108.0	109.1	−1.1	105.5	108.6	−3.1
	SD:	13.3	14.5		13.9	14.0		11.9	13.0		13.0	14.0	
Short-Term Memory (*Gsm*)	*M*:	105.1	101.8	3.3	105.8	105.8	0.0	108.4	108.3	0.1	105.1	105.4	−0.3
	SD:	12.2	13.7		13.6	12.7		10.3	11.6		12.8	13.0	

Table 3 (*continued*)

Variable		Age 5–6 Male SS	Female SS	M–F SS	Age 7–9 Male SS	Female SS	M–F SS	Age 10–13 Male SS	Female SS	M–F SS	Age 14–18 Male SS	Female SS	M–F SS
Achievement													
Reading (*Grw*)	*M*:	106.2	103.8	2.4	107.3	108.9	−1.6	110.3	108.9	1.3	105.5	105.4	0.1
	SD:	11.2	11.2		11.3	9.3		9.3	10.4		10.6	9.2	
Math (*Gq*)	*M*:	105.2	99.4	5.8	107.7	105.3	2.4	113.7	104.6	9.2	103.7	101.8	1.8
	SD:	12.4	12.2		16.2	10.6		11.4	10.3		11.1	11.5	
Writing (*Grw*)	*M*:	102.4	105.0	−2.6	103.9	109.9	−6.0	106.2	111.2	−5.0	104.6	106.9	−2.3
	SD:	10.2	12.0		11.2	9.8		8.9	11.4		9.7	10.4	
Academic Knowledge (*Gc*)	*M*:	108.5	100.9	7.6	107.1	103.9	3.2	116.3	107.6	8.7	106.8	103.8	3.0
	SD:	12.7	11.6		11.2	9.3		12.4	9.8		11.6	11.1	

Variable		Age Total Male SS	Female SS	M–F SS
	n:	885	1102	
General Intellectual Ability	*M*:	103.9	104.4	−0.5
	SD:	14.0	13.9	
Broad CHC Abilities				
Verbal Ability (Gc)	*M*:	104.8	102.9	1.9
	SD:	13.9	13.9	
Long-Term Retrieval (Glr)	*M*:	104.0	105.2	−1.2
	SD:	13.6	14.1	
Visual-Spatial Thinking (Gv)	*M*:	102.7	104.2	−1.5
	SD:	14.1	14.4	
Auditory Processing (Ga)	*M*:	103.5	104.6	−1.0
	SD:	14.5	13.9	
Fluid Reasoning (Gf)	*M*:	102.8	102.9	−0.2
	SD:	14.0	13.6	
Processing Speed (*Gs*)	*M*:	100.9	106.2	−5.3
	SD:	14.3	14.2	
Short-Term Memory (*Gsm*)	*M*:	103.8	103.1	0.7
	SD:	14.4	13.8	
Achievement				
Reading (*Grw*)	*M*:	103.8	104.9	−1.1
	SD:	12.9	12.0	
Math (*Gq*)	*M*:	104.1	102.1	2.0
	SD:	13.2	12.3	
Writing (*Grw*)	*M*:	101.8	105.8	−4.0
	SD:	12.1	11.9	
Academic Knowledge (*Gc*)	*M*:	105.0	102.2	2.8
	SD:	14.0	13.1	

Mean differences computed prior to rounding.

[a] 17–34 years of age.

different from one another, the middle and high school students were also not different from one another, and the three adult cohorts were not different. The significant interaction effect was generated because although females showed higher standard scores than males in all cohorts, this difference was much larger in the middle school and high school cohorts. Post hoc testing indicated that *Gs* was not different in two of the three adult cohorts, but males and females in the child and adolescent cohorts (i.e. elementary, middle school and high school cohorts) were significantly different from one another with an increasing magnitude in this difference through high school. There was a maximum of 8.1 ($d=0.553$) standard score points sex difference for *Gs* observed in the high school cohort before shrinking to a nonsignificant 0.22 (107.76 in males and

107.98 in females) difference in young adults. It appears that the pronounced processing speed difference in adolescents rapidly diminished in young adults.

2.3. Verbal abilities

Interestingly, a smaller but significant sex difference was also evident for Verbal Ability (*Gc*). But, in this broad ability, in contrast to *Gs*, females scored significantly lower than males, $F(1, 1721)=10.01$, $p<0.0001$. Conversely, there was no main effect in college students, $F(1, 250)=0.37$, $p>0.50$. In the noncollege sample, there was also a main effect for age, $F(6, 1721)=12.79$, $p<0.0001$. The age effect was generated because the mean scores in the adult groups were higher than in the child and adolescent groups. There was no significant interaction effect, $F(6, 1721)=1.49$, $p>0.05$. We wish to highlight the main effect showing a sex difference and the direction of this finding as it was perhaps the reverse of a priori prediction: In this database, the males scored significantly higher than females for estimates of verbal ability. This difference was observed in all cohorts, with the exception of middle age adults and college students, who were not significantly different. The overall mean for males was 104.8 as compared to 102.9 for females, with a d value of 0.137.

Unlike the results for Processing Speed (*Gs*), favoring females, and to a lesser degree, for Verbal Ability (*Gc*), favoring males, there were no significant sex differences observed in the remaining broad abilities on the WJ III. The broad abilities for which no significant sex differences were observed include: Long-Term Retrieval (*Glr*), Visual-Spatial Abilities (*Gv*), Auditory Processing (*Ga*), Fluid Reasoning (*Gf*) and Short Term Memory (*Gsm*). The results for these remaining broad abilities are presented below.

2.4. Long term retrieval

There was no significant difference between females and males for Long-Term Retrieval (*Glr*), $F(1, 1721)=1.04$, $p>0.35$ and there was no significant sex by age interaction, $F(6, 1721)=0.80$, $p>0.40$, but there was a significant main effect for age, $F(6, 1721)=21.85$, $p<0.0001$ with the kindergarten and elementary school children and the adult cohorts having higher standard score means than the middle and high school cohorts. The kindergarten and elementary school cohorts and adult cohorts were not different from one another nor were the middle and high school cohorts. Similarly, there was no sex difference in the college sample, $F(1, 250)=0.25$, $p>0.50$.

2.5. Visual spatial abilities

For Visual-Spatial (*Gv*) abilities, there was no significant main effect for sex, $F(1, 1721)=2.29$, $p>0.05$, nor was there a significant interaction, $F(6, 1721)=1.00$, $p>0.30$, but a significant main effect for age was observed, $F(6, 1721)=7.89$, $p<0.001$. The age effect was generated because elementary and middle school children standard score means were lower than the kindergarten and high school cohorts and the adult cohorts whereas the elementary and middle school cohorts were not different than one another nor were the kindergarten, high school or adult cohorts different. Nor was there a sex difference in the college sample, $F(1, 250)=0.05$, $p>0.50$.

2.6. Auditory processing

There was no main effect for sex, $F(1, 1721)=0.80$, $df=1, 1721$, $p>0.30$ in the broad group or in the sample of college students, $F(1, 250)=0.05$, $p>0.50$, nor was there a significant interaction effect, $F(6, 1721)=2.07$, $p>0.05$ in auditory processing skills (*Ga*). As with *Glr* and *Gv*, there was a main effect for age, $F(6, 1721)=9.54$, $p<0.001$ in the sample excluding college students. The kindergarten, elementary and adult cohorts were higher than middle school and high school students. The kindergartener, elementary and adult cohorts were not different. The middle and high school students were also not different. This directly parallels the pattern observed for *Glr*.

2.7. Fluid reasoning

Fluid Reasoning (*Gf*) was not different for females and males ($F(1, 1721)=1.19$, $p>0.20$) or the college sample, $F(1, 250)=0.26$, $p>0.50$. There was a significant main effect for age, $F(6, 1721)=7.16$, $p<0.01$, and there was a significant age by sex interaction, $F=(6, 1721)=2.30$, $p<0.05$ in the sample excluding college students. In terms of age cohort, the kindergartener and adult cohorts were significantly higher than the other child and adolescent groups. The kindergarten and adult cohorts were not different and the elementary, middle school and high school cohorts were not different. The interaction effect was generated because male and female differences shifted in the various cohorts. Kindergarten, middle school, young adult and elderly cohorts revealed higher (but not significant) scores for males whereas the remaining cohorts (elementary, high school, and middle age) were higher (but not significant) for females. This interaction effect is difficult to interpret and may simply be random oscillation around relatively similar means ($M=102.8$ for males and $M=102.9$ in females for the overall sample) rather than a meaningful developmental pattern.

2.8. Short-term memory

There was no difference between females and males, $F(1, 1721)=0.78$, $p>0.50$ for Short-Term memory (*Gsm*) and no difference in the college sample $F(1, 250)=0.026$, $p>0.50$, and no significant interaction effect, $F=1.07$, $p>0.30$. There was a significant main effect for age, $F(6, 1721)=5.23$, $p<0.05$. Higher scores for the kindergarten, middle and senior cohorts as compared to the elementary, middle, high school and young adult cohorts generated the main effect for age.

2.9. Academic knowledge

In order to gain insight into the potential impact of the sex differences in *Gs* and *Gc*, the WJ III estimate of academic knowledge was also compared between sex and across age levels. There was a significant main effect for sex, $F(1, 1721)=17.61$, $p<0.0001$, with males scoring higher than females by 2.8 points on average ($d=0.207$). This was also seen in the college sample, $F(1, 249)=4.26$, $p<0.05$, M for females $=103.8$ and M for males $=106.8$, $d=0.264$). There was also a significant main effect for age $F(6, 1721)=12.44$, $p<0.0001$). This age effect was generated by significantly higher scores in the senior group as compared to the other cohorts, which were not different. There was a significant interaction effect $F(6, 1721)=3.42$, $p<0.05$: The kindergarten and high school males and females were not different, but the mean standard scores for elementary, middle school and all three cohorts of adult males were significantly higher than females. The actual Academic Knowledge main effect for sex is based upon a relatively small difference (pooled male $M=105.0$, pooled female $M=102.2$), but it is noteworthy that males are higher than females in light of the higher female performance in processing speed. The magnitude and direction of this difference parallels that seen in *Gc* with a d value of 0.207.

2.10. Math, reading, and writing achievement

In addition to the broad CHC abilities, the participants in this study also completed achievement testing. Because of the strong difference in processing speed, the focus of this analysis is comparing untimed estimates of math, reading and writing ability to timed measures of these domains.

For Math Achievement, which is untimed, males were significantly higher than females (mean difference $=2.0$, $d=0.146$, $F(1, 1721)=7.30$, $p<0.01$), and there were significant age, $F(6, 1721)=13.44$, $p<0.0001$, and interaction effects, $F(6, 1721)=3.74$, $p<0.001$ as well. There was no difference in the college sample: Female $M=101.8$ and male $M=103.7$, $F(1, 250)=1.56$, $p>0.20$. The age difference was a result of relatively lower performance in middle school and high school cohorts as compared to younger cohorts and to the adult cohorts. The interaction effect was generated because males and females were not different in the kindergarten, elementary, middle school, and college samples, but increasingly different (with males higher) in the high school and adult cohorts. For Math Fluency, which is a timed test and presumably related to processing speed, there was no significant difference in Math Fluency (mean standard score difference $=1.7$, $F(1, 1721)=2.55$, $p>0.05$). This was also evident in the college sample: M for females $=104.4$ and M for males $=103.2$, $F=(1, 250)=0.87$, $p>0.30$. In Math, untimed achievement was higher in males, but this advantage disappeared when measured using a timed test.

Reading Achievement was not different, $F(1, 1721)=2.17$, $p>0.10$ in females and males and there was no significant difference in the college sample, $F(1, 250)=0.004$, $p>0.50$. Nor was there a significant age by sex interaction $F(6, 1721)=0.76$, $p>0.50$. There was however, an age difference $F(6, 1721)=11.08$, $p<0.0001$, with the adult cohorts having higher reading achievement as compared to the child and adolescent cohorts. In contrast, Reading Fluency, which is timed, was significantly higher in females when compared to males: Mean standard score difference $=5.0$, $d=0.333$, $F(1, 1721)=38.38$, $p<0.0001$. This was also seen in the college sample (male $M=100.8$, female $M=107.3$, $d=0.415$), $F(1, 250)=14.08$, $p<0.0001$. For Reading, there was no difference in the untimed achievement levels, but females were significantly higher when this skill was measured with a timed test.

For Writing Achievement, measured using an untimed test, females scored an average of 4.0 standard score points higher than males ($d=0.333$), $F(1, 1721)=44.32$, $p<0.0001$, a significant difference. This was not seen in the college students, $F(1, 250)=3.02$, $p>0.05$ although college females scored an average of 2.3 standard score points higher. There was a significant effect for age $F(6, 1721)=16.03$, $p<0.0001$, with the school age cohorts scoring lower than the adult cohorts. There was no interaction effect because the main effect for females was evident in all cohorts. In Writing Fluency, which is a timed test, the mean standard score difference increased to 7.1 ($d=0.444$) a significant advantage for females, $F(1, 1721)=40.87$, $p<0.0001$. In college students, females scored an average of 8.3 points higher than males ($d=0.417$), which was a significant difference, $F(1, 250)=14.02$, $p<0.0001$. For writing ability, an untimed advantage for females grew even larger when measured using a timed test. It is perhaps noteworthy that the post hoc testing indicated that this disparity in Writing Fluency was evident in all cohorts and that the magnitude of this difference was even larger than would have been predicted simply on the basis of sex differences in achievement in writing.

2.11. Summary of results for WJ III cognitive and achievement scores

The analyses provided evidence of sex differences on two abilities (*Gs* and *Gc*) and for Academic Knowledge (which is related to *Gc*). There were highly significant sex differences for processing speed with females scoring significantly higher than males in all cohorts. The magnitude of these differences was greater than one-half standard score deviation in the middle school and high school cohorts, but was relatively small in kindergarteners and in young adults. A secondary consistent finding was the smaller, but consistently higher levels of verbal performance for males as compared to females. Similarly, in direct concordance with the results from *Gc*, standard scores for mean Academic Knowledge were slightly, but significantly greater in males than females. These results were evident in the absence of differences in General Intellectual Abilities or for the remaining broad abilities, including Long-Term Retrieval, Visual-Spatial Thinking, Auditory Processing, Fluid Reasoning, and Short-Term Memory.

It is perhaps also noteworthy that a significant sex by age interaction effect for processing speed (*Gs*) was driven by increasing disparities in successively older school age cohorts before shrinking again in young adults. That is, the *Gs* means were relatively close in male and female kindergarteners but the advantage for females became progressively greater and was more than one-half standard score deviation in the high school cohort. The difference narrowed again in the young adult cohort. For achievement tests, males performed significantly higher than females in math, females were higher in writing and there was no difference in reading. In the analysis of achievement within the context of processing speed (timed measures), females were significantly higher than males for both Reading and for Writing Fluency. In the latter skill, females were higher in all cohorts across the lifespan. There was no sex difference in Math Fluency.

2.12. Post hoc analysis of the narrow abilities contributing to processing speed and verbal abilities

Because the WJ III is constructed so that relatively broad abilities such as *Gs* (processing speed) and *Gc* (verbal abilities) are estimated using a mix of narrow abilities, it may be useful to follow up the consistent, significant sex differences for *Gs* and *Gc* by examining the component narrow abilities. The cluster score for *Gs* includes Visual Matching and Decision Speed. In addition, other tests measuring *Gs* include Rapid Picture Naming and Cross Out. In order to determine the ways that each of these abilities contributed to overall poorer performance for males, post hoc analyses of variance were completed on the overall WJ III standardization sample on these narrow abilities using bootstrapping statistical analyses. Note that the average difference was approximately four points higher overall for females, so that the relative contribution of each narrow ability can be referenced to the overall disparity in *Gs*.

The results of these analyses indicated significant sex differences in most narrow abilities measures of *Gs*, with females scoring significantly higher than males as one would expect. But, these scores were not equally distributed across all tests. Visual Matching (mean difference $=4.0$, $d=0.274$), $F(1, 2138)=8.89$, $p<0.0005$, Rapid Picture Naming (mean score difference $=3.0$, $d=0.206$), $F(1, 2138)=11.67$, $p<0.001$ and Decision Speed (mean difference $=3.9$, $d=0.262$), $F(1, 2138)=4.95$, $p<0.05$, were relatively larger differences. There was no significant difference observed for Cross Out (mean score difference $=2.0$), $F(1, 2138)=2.58$, $p>0.05$. There was a significant difference that favored females as well for Retrieval Fluency, which is a timed test, but a measure of *Glr* rather than *Gs* (mean standard score difference $=3.6$, $d=0.271$), $F(1, 2487)=21.87$, $p<0.0001$. In the college sample, significantly higher means for females were observed in Visual Matching (mean difference of 3.4, $d=0.239$), Decision Speed (mean difference of 3.6, $d=0.252$) and Cross Out (mean difference of 3.8, $d=0.292$). No significant differences were noted in Rapid Picture Naming (mean difference of 0.2). Recall that in other timed tests, which do not directly contribute to the *Gs* score, but nonetheless are related to processing speed, with the exception of Math Fluency, were significantly higher in females. The results for these selected narrow abilities are presented in Table 4.

With regard to verbal abilities, Verbal Comprehension and General Information are the narrow ability tests that contribute to *Gc* on the WJ III. A related test

Table 4
WJ III (2001): Male–female selected narrow abilities standard score by age level

Variable		Age 5–6 Male SS	Female SS	M–F SS	7–9 Male SS	Female SS	M–F SS	10–13 Male SS	Female SS	M–F SS	14–18 Male SS	Female SS	M–F SS	19–34 Male SS	Female SS	M–F SS
	n:	26	20		214	248		306	281		231	243		74	127	
Cognitive Speed																
Visual	*M*:	107.3	108.4	−1.0	101.6	104.4	−2.8	96.7	101.2	−4.5	98.5	102.7	−4.2	105.9	104.3	1.6
Matching	SD:	14.8	10.6		14.1	14.8		14.0	14.6		13.5	14.4		16.0	14.6	
Decision	*M*:	108.5	103.7	4.8	100.8	104.0	−3.1	98.0	104.1	−6.2	98.0	102.4	−4.4	104.0	106.1	−2.1
Speed	SD:	11.7	12.1		15.7	13.0		14.7	14.6		14.0	15.9		14.5	17.7	
Rapid Picture	*M*:	104.6	109.5	−4.8	99.0	102.6	−3.5	97.0	100.9	−4.0	101.7	104.0	−2.4	100.9	104.1	−3.3
Naming	SD:	14.3	18.2		13.8	13.4		15.2	14.1		14.8	15.2		13.0	14.1	
Cross Out	*M*:	106.3	110.3	−4.0	100.6	101.6	−0.9	100.3	102.6	−2.4	99.6	102.7	−3.0	105.0	101.2	3.9
	SD:	11.8	16.4		13.2	13.7		14.4	14.0		14.6	14.2		13.3	13.7	
Retrieval	*M*:	98.1	107.0	−8.8	100.9	103.3	−2.3	100.5	103.3	−2.8	100.2	105.2	−5.0	105.4	106.8	−1.5
Fluency	SD:	12.2	11.6		13.1	14.0		13.3	14.3		13.1	14.5		11.3	12.5	
Achievement Speed																
Reading	*M*:	95.4	107.2	−11.9	102.3	104.5	−2.3	98.8	103.3	−4.5	98.6	104.4	−5.8	104.0	104.9	−0.9
Fluency	SD:	18.1	16.5		14.4	12.9		13.2	15.8		14.2	16.6		15.6	16.2	
Math Fluency	*M*:	103.6	106.9	−3.2	102.2	102.7	−0.5	98.1	100.3	−2.2	98.5	100.0	−1.5	104.3	102.0	2.3
	SD:	9.0	11.5		13.9	13.0		16.4	15.3		14.5	13.7		13.7	13.3	
Writing	*M*:	99.8	103.0	−3.3	99.4	105.4	−6.0	97.0	102.8	−5.8	98.5	103.4	−4.9	103.0	106.8	−3.8
Fluency	SD:	13.1	10.1		14.2	14.6		15.0	14.9		14.3	13.4		12.1	16.1	

Variable		Age 35–49 Male SS	Female SS	M–F SS	50–79 Male SS	Female SS	M–F SS	College[a] Male SS	Female SS	M–F SS	Total Male SS	Female SS	M–F SS
	n:	77	128		62	115		132	217		1122	1379	
Cognitive Speed													
Visual Matching	*M*:	102.0	107.9	−5.9	106.2	107.5	−1.3	104.3	107.7	−3.4	100.6	104.6	−4.0
	SD:	14.5	13.2		14.5	16.1		13.9	14.5		14.5	14.7	
Decision Speed	*M*:	102.8	109.1	−6.3	105.7	102.2	3.5	97.3	101.0	−3.6	99.8	103.8	−3.9
	SD:	13.5	15.1		14.2	13.8		15.8	13.6		15.0	14.8	
Rapid Picture	*M*:	104.6	107.6	−3.0	107.7	107.3	0.4	100.8	100.6	0.2	100.3	103.3	−3.0
Naming	SD:	11.9	12.7		13.1	14.0		15.6	14.5		14.7	14.4	
Cross Out	*M*:	103.1	108.0	−4.9	105.5	103.6	1.9	99.6	103.4	−3.8	101.1	103.1	−2.0
	SD:	12.8	12.5		13.5	12.6		14.4	11.6		14.0	13.5	
Retrieval	*M*:	104.0	106.8	−2.8	108.5	110.3	−1.8	108.8	110.6	−1.7	102.4	106.1	−3.6
Fluency	SD:	10.4	8.7		13.1	12.8		12.2	12.6		13.1	13.5	
Achievement Speed													
Reading Fluency	*M*:	102.9	110.8	−7.9	107.6	108.1	−0.5	100.8	107.3	−6.5	100.7	105.7	−5.0
	SD:	11.2	14.1		14.5	14.9		15.6	15.7		14.4	15.4	
Math Fluency	*M*:	102.8	107.5	−4.7	109.9	107.1	2.9	103.2	104.4	−1.3	101.1	102.8	−1.7
	SD:	15.7	13.2		14.2	13.5		13.0	11.6		15.0	13.7	
Writing Fluency	*M*:	101.1	111.6	−10.5	106.0	109.2	−3.2	113.3	121.7	−8.3	100.9	108.1	−7.1
	SD:	11.5	12.5		15.0	14.0		19.6	20.5		15.7	16.7	

Mean differences computed prior to rounding.
[a] 17–34 years of age.

is Academic Knowledge. These areas were also tested using an analysis of variance. Recall that the results of the statistical test on *Gc* indicated that males were significantly higher than females, and that the mean difference was approximately 1.9 standard score units. The results of the post hoc analysis indicated that males were significantly higher for both Verbal Comprehension and for General Information. The average standard score difference for Verbal Comprehension was 1.8 ($d = 0.121$) whereas the difference was 2.2 ($d = 0.147$) on average for General Information. Both of these differences are statistically significant, $F(1, 1343) = 7.70$, $p < 0.01$ and $F(1, 1343) = 8.17$, $p < 0.01$, respectively. Recall that there was a significant difference for the related ability of Academic Knowledge on the WJ III, with males averaging approximately 2.8 standard score units higher than females ($d = 0.207$).

2.13. WJ-77 and WJ-R replication analyses

Although the construct sampling domains were slightly different for the WJ-R and for the WJ-77, estimates of processing speed could be derived from each of these instruments to determine whether the finding of relatively large male–female disparities in processing speed, and the other broad abilities were replicated in these earlier samples. In the WJ-77, Spatial Relations (a timed test in the WJ-77 and thus included as a measure of *Gs*) and visual matching were combined to generate a perceptual speed score as an estimate of *Gs*. On the WJ-R, the *Gs* (processing speed) factor was estimated by combining Visual Matching and Cross Out test scores. Standard scores were available for both the WJ-77 and WJ-R for the same age ranges used in the WJ III analyses: kindergarten (5–6 year olds), elementary (7–9 year olds), middle school (10–13 year olds), high school (14–18 year olds), young adult (19–34), middle age (35–49) and senior (50–79). The WJ-R also included a separate college sample. The mean standard scores for males and females across these cohorts were compared using analyses of variance.

2.14. Processing speed on the WJ-77 and WJ-R

The results of this analysis on WJ-77 and WJ-R data directly replicated the WJ III finding for *Gs*: males scored significantly lower than females for processing speed (*Gs*) on the WJ-77, $F(1, 4210) = 42.93$, $p < 0.0001$ and on the WJ-R, $F(1, 4079) = 145.02$, $p < 0.0001$. The mean difference on the college sample from the WJ-R was less than 1 (0.9 standard score points) and, as on the WJ III, was not significant, $F(1, 163) = 0.105$ $p > 0.50$. The magnitude of the difference was 3.8 standard score units on the WJ-77 ($d = 0.300$) and 6.8 ($d = 0.420$) on the WJ-R (excluding the college enrollees), results that are consistent with the WJ III results. Processing Speed and the other broad abilities on the WJ-77 and WJ-R are presented in Tables 5 and 6.

2.15. Narrow abilities contributing to processing speed on the WJ-R and WJ-77

The estimate of *Gs* On the WJ-R includes Visual Matching and Cross Out and there is a timed Writing Fluency test as well. The WJ-77 includes Visual Matching and Spatial Relations as estimates of Processing Speed and does not include Math Fluency, Reading Fluency, or Writing Fluency. There were consistent sex differences on all of the WJ-R and WJ-77 narrow abilities related to processing speed, with females consistently scoring significantly higher than males. These included mean differences of 5.9 standard score units for Visual Matching ($d = 0.371$), 4.9 for Cross Out ($d = 0.309$), and 6.0 for Writing Fluency ($d = 0.404$). Similarly, there was a difference of 4.8 standard score units on Visual Matching ($d = 0.326$) on the WJ-77 and a smaller, but significant difference for Spatial Relations (2.6 mean difference with $d = 0.176$). These results are presented in Table 7.

2.16. Verbal abilities on the WJ-77 and the WJ-R

As with Processing Speed, the results from the WJ III scores were directly replicated on the WJ-R database, but not for the WJ-77. The *Gc* estimate of verbal abilities was significantly higher for males on the WJ-R, $F(1, 4074) = 3.56$, $df = 1$, 4074, $p < 0.05$, for mean standard score difference on *Gc* (mean difference = 1.6 and $d = 0.101$). Interestingly, college enrolled males scored an average of 6.7 standard score points higher than females ($d = 0.462$), which was a significant difference ($F(1, 163) = 8.10$, $p < 0.005$. In contrast, the estimate of *Gc* was not different on the WJ-77, $F(1, 4211) = 1.56$, $p > 0.05$. It should be noted that the senior adult group in the WJ-77 sample was significantly higher for females ($M = 101.6$) as compared to males ($M = 97.8$). In the remaining cohorts, males were significantly higher than females. Thus, it appears that with the exception of the senior adult cohort, *Gc* was higher for males than females on the WJ-77. Therefore, the results from the WJ-R were consistent with the

Table 5
WJ-R (1989): Male–female broad abilities standard score by age level

Variable		Age 5–6 Male SS	5–6 Female SS	5–6 M–F SS	7–9 Male SS	7–9 Female SS	7–9 M–F SS	10–13 Male SS	10–13 Female SS	10–13 M–F SS	14–18 Male SS	14–18 Female SS	14–18 M–F SS
	n:	136	133		429	415		469	472		375	403	
General Intellectual	*M*:	100.0	102.7	−2.8	101.3	103.3	−2.0	99.8	102.1	−2.3	102.5	104.3	−1.8
Ability	SD:	14.0	13.7		16.3	16.0		14.4	15.4		17.4	16.9	
Broad CHC Abilities													
Verbal Ability (*Gc*)	*M*:	100.5	99.1	1.4	102.8	101.0	1.9	103.0	100.9	2.1	103.4	100.3	3.1
	SD:	15.1	14.8		16.1	16.0		15.8	14.8		16.0	17.0	
Long-Term Retrieval	*M*:	102.8	101.3	1.4	103.4	103.1	0.3	103.4	102.1	1.3	103.2	104.8	−1.6
(*Glr*)	SD:	15.7	15.6		16.5	16.9		15.6	14.8		16.6	16.5	
Visual-Spatial	*M*:	99.1	102.0	−2.8	101.2	102.4	−1.2	99.6	102.6	−3.0	100.1	103.4	−3.2
Thinking (*Gv*)	SD:	14.6	11.7		15.6	15.2		14.4	14.8		14.6	15.9	
Auditory Processing	*M*:	98.2	102.8	−4.5	102.7	103.7	−1.0	99.7	101.6	−1.9	101.3	102.1	−0.8
(*Ga*)	SD:	15.2	13.8		14.7	15.2		13.2	14.1		14.7	13.8	
Fluid Reasoning (*Gf*)	*M*:	99.2	100.0	−0.8	100.5	103.2	−2.7	100.3	101.6	−1.3	102.6	102.8	−0.2
	SD:	12.3	15.0		14.4	16.0		13.6	15.5		16.3	14.8	
Processing Speed (*Gs*)	*M*:	97.6	104.7	−7.1	97.4	103.3	−5.9	97.1	106.4	−9.3	99.9	106.6	−6.7
	SD:	16.3	13.4		16.6	15.5		14.7	16.0		16.9	16.1	
Short-Term Memory	*M*:	98.8	100.5	−1.7	101.7	103.2	−1.5	102.3	103.1	−0.8	102.2	103.6	−1.4
(*Gsm*)	SD:	15.0	14.6		15.8	14.8		15.0	15.7		16.1	16.5	
Achievement													
Reading (*Grw*)	*M*:	101.9	105.2	−3.3	101.8	105.3	−3.5	101.0	104.1	−3.0	102.3	103.7	−1.5
	SD:	15.4	12.3		13.7	13.7		13.2	13.6		15.1	14.3	
Math (*Gq*)	*M*:	100.9	100.9	−0.0	101.7	104.4	−2.6	101.3	103.1	−1.8	105.1	103.7	1.4
	SD:	13.1	12.3		15.3	14.2		13.1	12.7		17.3	15.0	
Writing (*Grw*)	*M*:	103.0	107.2	−4.2	98.8	105.9	−7.1	97.6	105.9	−8.2	100.4	106.2	−5.9
	SD:	11.4	11.3		13.6	13.8		14.2	15.1		15.0	14.5	
Academic Knowledge	*M*:	99.5	98.8	0.7	101.4	100.7	0.6	103.8	102.1	1.7	105.3	103.2	2.1
(*Gc*)	SD:	13.7	13.0		15.4	14.9		16.0	14.7		17.8	16.8	

Variable		Age 19–34 Male SS	19–34 Female SS	19–34 M–F SS	35–49 Male SS	35–49 Female SS	35–49 M–F SS	50–79 Male SS	50–79 Female SS	50–79 M–F SS	College[a] Male SS	College[a] Female SS	College[a] M–F SS
	n:	186	240		143	192		217	278		59	106	
General Intellectual	*M*:	95.1	100.4	−5.3	97.6	100.8	−3.2	98.5	103.1	−4.6	111.7	106.4	5.4
Ability	SD:	18.1	15.1		15.5	15.8		18.3	14.4		14.2	13.9	
Broad CHC Abilities													
Verbal Ability (*Gc*)	*M*:	97.8	99.5	−1.7	101.0	99.3	1.7	101.0	102.2	−1.2	110.1	103.4	6.7
	SD:	17.8	15.8		16.2	16.1		16.9	14.1		14.5	14.5	
Long-Term Retrieval	*M*:	97.2	101.4	−4.2	97.0	104.0	−7.0	99.4	104.5	−5.1	107.4	104.7	2.7
(*Glr*)	SD:	16.8	15.7		14.5	16.1		17.4	14.8		15.3	14.4	
Visual-Spatial	*M*:	96.6	102.0	−5.4	98.4	102.2	−3.8	99.2	105.5	−6.3	101.8	101.6	0.2
Thinking (*Gv*)	SD:	16.9	15.5		14.1	14.4		17.1	14.9		15.6	12.0	
Auditory Processing	*M*:	96.9	102.3	−5.4	99.2	101.6	−2.4	98.9	104.6	−5.8	109.7	106.1	3.5
(*Ga*)	SD:	16.9	17.1		15.1	14.6		15.4	14.0		15.8	13.0	
Fluid Reasoning (*Gf*)	*M*:	95.4	97.8	−2.4	98.0	100.8	−2.9	102.2	102.0	0.2	110.7	107.3	3.4
	SD:	17.0	14.7		14.6	14.7		18.3	14.1		15.8	14.0	
Processing Speed (*Gs*)	*M*:	93.3	101.8	−8.6	98.7	102.0	−3.3	99.5	105.5	−6.0	106.8	107.7	−0.9
	SD:	18.3	15.7		16.9	15.1		16.8	16.4		16.6	16.6	
Short-Term Memory	*M*:	99.8	101.8	−1.9	102.0	102.4	−0.4	101.8	103.7	−1.9	109.7	103.9	5.8
(*Gsm*)	SD:	15.7	14.9		14.7	16.7		17.5	14.6		15.6	15.3	

(continued on next page)

Table 5 (*continued*)

Variable		Age											
		5–6			7–9			10–13			14–18		
		Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS
Achievement													
Reading (*Grw*)	*M*:	97.1	100.2	−3.1	100.2	102.6	−2.4	100.6	104.4	−3.7	110.4	106.1	4.3
	SD:	18.2	15.4		15.6	15.9		15.2	12.3		15.4	13.7	
Math (*Gq*)	*M*:	98.9	96.6	2.3	104.5	100.0	4.6	104.0	100.7	3.2	116.0	105.9	10.2
	SD:	17.3	12.4		15.6	14.5		19.1	12.8		18.2	13.6	
Writing (*Grw*)	*M*:	95.0	101.0	−6.0	99.3	102.9	−3.6	99.3	104.8	−5.5	106.2	108.6	−2.4
	SD:	15.4	13.8		16.6	15.0		15.1	13.9		13.1	12.6	
Academic Knowledge (*Gc*)	*M*:	100.2	98.6	1.6	103.4	100.3	3.1	101.9	101.8	0.1	113.4	105.8	7.6
	SD:	18.5	14.4		15.5	14.4		15.8	12.9		15.7	13.7	

Variable		Total		
		Male SS	Female SS	M–F SS
	n:	2014	2239	
General Intellectual Ability	*M*:	100.2	102.8	−2.5
	SD:	16.5	15.6	
Broad CHC Abilities				
Verbal Ability (*Gc*)	*M*:	102.2	100.7	1.6
	SD:	16.3	15.6	
Long-Term Retrieval (*Glr*)	*M*:	102.0	103.2	−1.3
	SD:	16.4	15.8	
Visual-Spatial Thinking (*Gv*)	*M*:	99.7	102.9	−3.2
	SD:	15.3	14.9	
Auditory Processing (*Ga*)	*M*:	100.5	102.8	−2.4
	SD:	14.9	14.6	
Fluid Reasoning (*Gf*)	*M*:	100.6	101.9	−1.3
	SD:	15.4	15.2	
Processing Speed (*Gs*)	*M*:	98.0	104.8	−6.8
	SD:	16.6	15.8	
Short-Term Memory(*Gsm*)	*M*:	101.8	103.0	−1.1
	SD:	15.8	15.5	
Achievement				
Reading (*Grw*)	*M*:	101.3	103.9	−2.6
	SD:	14.9	14.0	
Math (*Gq*)	*M*:	102.8	102.2	0.6
	SD:	16.1	13.8	
Writing (*Grw*)	*M*:	99.1	105.2	−6.2
	SD:	14.6	14.3	
Academic Knowledge (*Gc*)	*M*:	103.0	101.5	1.5
	SD:	16.4	14.8	

Mean differences computed prior to rounding.
[a] 17–34 years of age.

results from the WJ III, and, with the exception of the senior adult cohort, on the WJ-77 as well.

2.17. Academic knowledge on the WJ-77 and the WJ-R

There was replication on the WJ III findings for overall estimates of academic knowledge as well. Recall that males scored 2.8 units higher than females on Academic Knowledge on the WJ III ($d=0.207$). There was also a significant sex difference on the parallel factor of the WJ-R (Broad Knowledge), with an average difference of 1.5 standard score units ($d=0.096$). The males enrolled in college were significantly higher than female college enrollees by an average of 7.6 standard score units ($d=0.507$). Similarly, the WJ-77 factor Knowledge, was significantly higher for males by an average of 3.0 standard score units ($d=0.227$). In all three batteries, the estimate for this ability was

Table 6
WJ-77 (1977): Male–female broad abilities standard score by age level

Variable		Age											
		5–6			7–9			10–13			14–18		
		Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS
	n:	333	344		458	529		582	688		405	471	
General Intellectual	*M*:	98.1	100.7	−2.6	98.8	100.2	−1.4	99.7	99.6	0.1	100.4	99.1	1.3
Ability	SD:	15.5	14.4		14.8	15.0		15.0	14.8		14.4	15.1	
Broad CHC Abilities													
Verbal Ability (*Gc*)	*M*:	99.6	99.6	0.0	100.4	98.9	1.5	101.0	98.4	2.6	101.7	98.2	3.5
	SD:	12.8	11.8		12.6	12.7		12.9	13.0		12.9	13.2	
Long-Term Retrieval	*M*:	98.3	100.1	−1.8	98.4	100.5	−2.2	99.2	100.1	−0.8	97.8	101.2	−3.4
(*Glr*)	SD:	14.3	15.2		14.3	15.4		14.9	15.0		12.9	16.4	
Auditory Processing	*M*:	97.9	100.8	−2.9	98.4	100.7	−2.3	98.5	100.5	−2.0	98.7	100.7	−2.0
(*Ga*)	SD:	15.9	13.8		15.2	14.5		15.2	14.6		14.3	15.5	
Fluid Reasoning (*Gf*)	*M*:	98.4	100.5	−2.1	98.3	100.5	−2.3	99.5	99.7	−0.3	100.1	99.3	0.8
	SD:	12.1	13.2		13.1	12.1		12.9	12.6		12.8	12.8	
Processing Speed (*Gs*)	*M*:	97.2	101.8	−4.6	97.9	101.3	−3.4	97.4	101.5	−4.1	98.2	100.9	−2.7
	SD:	13.7	11.5		12.0	12.5		12.4	12.3		12.0	12.6	
Short-Term Memory	*M*:	99.1	100.0	−0.9	98.8	100.3	−1.5	99.6	99.5	0.1	100.1	99.3	0.8
(*Gsm*)	SD:	13.2	12.5		12.2	12.7		12.3	12.0		11.9	13.1	
Achievement													
Reading (*Grw*)	*M*:	98.5	100.6	−2.1	98.3	100.8	−2.5	99.0	100.2	−1.2	99.2	99.9	−0.7
	SD:	14.2	13.3		15.0	13.1		13.9	13.3		14.2	13.0	
Math (*Gq*)	*M*:	98.5	100.5	−2.0	99.0	100.0	−1.0	99.7	99.8	−0.1	101.7	98.0	3.8
	SD:	13.4	12.1		14.5	12.8		13.8	13.1		14.5	13.1	
Writing (*Grw*)	*M*:	98.2	101.1	−2.9	97.3	101.6	−4.4	96.7	102.3	−5.6	97.0	102.3	−5.2
	SD:	12.4	12.9		14.2	13.4		14.3	13.1		14.7	12.8	
Academic Knowledge	*M*:	99.5	99.5	−0.0	100.7	98.6	2.1	102.1	97.6	4.5	102.6	97.4	5.2
(*Gc*)	SD:	14.3	12.7		12.8	12.9		13.1	13.2		12.8	13.4	

Variable		Age											
		19–34			35–49			50–79			Total		
		Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS
	n:	63	72		52	62		71	95		1964	2261	
General Intellectual	*M*:	97.6	99.7	−2.1	101.4	101.3	0.2	95.9	101.7	−5.8	99.2	99.9	−0.7
Ability	SD:	15.8	14.6		14.8	15.5		15.0	15.2		14.9	14.9	
Broad CHC Abilities													
Verbal Ability (*Gc*)	*M*:	98.9	98.1	0.8	101.0	100.3	0.7	97.8	101.6	−3.9	100.6	98.8	1.7
	SD:	14.0	14.2		14.2	13.5		13.3	13.2		12.9	12.9	
Long-Term Retrieval	*M*:	95.5	102.3	−6.8	100.3	105.2	−4.9	94.9	101.2	−6.3	98.3	100.7	−2.3
(*Glr*)	SD:	13.0	16.7		14.9	15.2		13.2	14.6		14.1	15.5	
Auditory Processing (*Ga*)	*M*:	96.1	100.6	−4.5	98.7	103.6	−4.9	94.0	103.8	−9.8	98.2	100.8	−2.7
	SD:	14.8	14.1		13.8	15.4		12.4	15.4		15.0	14.7	
Fluid Reasoning (*Gf*)	*M*:	100.1	99.8	0.3	100.0	99.8	0.2	97.8	100.0	−2.1	99.1	100.0	−0.9
	SD:	13.4	12.6		12.5	14.6		13.4	12.6		12.8	12.7	
Processing Speed (*Gs*)	*M*:	97.2	101.9	−4.7	100.7	100.8	−0.1	95.6	102.6	−7.0	97.7	101.4	−3.8
	SD:	12.0	13.2		12.6	13.9		11.8	11.7		12.4	12.3	
Short-Term Memory	*M*:	97.9	99.7	−1.7	100.6	101.7	−1.1	96.6	102.1	−5.5	99.3	99.9	−0.6
(*Gsm*)	SD:	15.4	11.9		11.7	13.8		12.0	11.6		12.4	12.5	
Achievement													
Reading (*Grw*)	*M*:	95.5	101.4	−5.9	99.9	101.4	−1.5	97.3	101.5	−4.2	98.7	100.5	−1.8
	SD:	16.7	12.1		14.7	13.3		12.9	13.2		14.4	13.1	
Math (*Gq*)	*M*:	101.7	97.0	4.7	102.4	99.3	3.1	99.1	98.3	0.8	99.9	99.4	0.5
	SD:	15.9	10.8		15.7	12.5		14.2	15.1		14.2	12.9	

(continued on next page)

Table 6 (*continued*)

Variable		Age											
		5–6			7–9			10–13			14–18		
		Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS
Writing (*Grw*)	*M*:	94.1	102.4	−8.3	97.3	102.8	−5.6	95.9	102.7	−6.8	97.1	102.0	−4.9
	SD:	16.4	11.5		14.0	13.6		14.0	14.3		14.1	13.1	
Academic Knowledge (*Gc*)	*M*:	101.0	97.9	3.1	101.8	99.5	2.4	98.4	100.2	−1.8	101.3	98.3	3.0
	SD:	14.4	12.2		13.4	13.2		13.9	13.5		13.3	13.1	

Mean differences computed prior to rounding.

significantly higher in males, with the magnitude of the difference being relatively small except in the WJ-R college sample, which was substantially higher for males.

2.18. Additional broad abilities on the WJ-77 and the WJ-R

Although the WJ III core findings for higher mean processing speed standard scores in females and greater mean verbal abilities standard scores and academic knowledge in males were replicated in the WJ-77 and WJ-R data, there were some findings that were not fully replicated across all three batteries. This is perhaps not surprising because there are several differences in the WJ III, WJ-R, and WJ-77 batteries and databases.

The degree of replication is presented in Table 8. This table includes the direction and magnitude of the standard score differences in males and females across abilities and across samples. Perhaps the most striking aspect of these data is the high concordance for direction of difference. There are a total of 12 broad abilities, narrow abilities, and achievement that are compared for the WJ III, WJ-R and WJ-77. An additional three abilities are included in the WJ III and WJ-R databases. In eleven of the twelve comparisons across all three databases, the direction of the difference is identical. The lone exception is for short-term memory (*Gsm*), with differences of 0.7 on the WJ III, −1.1 on the WJ-R and −0.6 on the WJ-77, respectively. None of these is a significant difference and the inconsistency perhaps reflects variation around no difference in males and females. The three WJ III and WJ-R sex differences were consistent with regard to direction. In addition to direction of the sex difference, the actual magnitude of the difference was also remarkably consistent across databases.

In summary, the significant sex differences for processing speed (females higher), for verbal abilities and academic knowledge (both slightly higher for males), and short term memory (not different in males and females) were directly replicated on the WJ III, WJ-R and the WJ-77. With the exception of auditory processing, which was not different on the WJ III, but was higher for females on both the WJ-R and WJ-77, the results from the WJ III analyses were consistently replicated with regard to direction of difference or partially replicated with regard to magnitude of the difference on either the WJ-R or the WJ-77. It is perhaps also noteworthy that there was no case of a significant finding being reversed with regard to directionality. That is, the disagreements in test findings included only contrasts between a significant difference on one test conflicting with a finding of no difference on another. It is striking that in no case was a significant sex difference reversed in another battery.

2.19. Analysis of sex difference across percentile ranks

The above analyses indicate a consistent, replicated significant male–female difference in processing speed. But these results do not indicate whether the difference is the result of relatively consistent differences across the sampling distribution or whether the difference is attributable to the lowest performing males being far below females while the remainder of the distribution is relatively similar. In order to examine this question, the WJ III processing speed standard scores were compared across selected percentiles for males and females. The results of this analysis indicate that males are consistently lower than females at all percentile levels. That is, males in the 10th percentile are a mean of 6.0 standard score points below females at the 10th percentile, 5.0 points below females at the 50th percentile and males at the 90th percentile are an average of 7.0 points below females at the 90th percentile. Thus, the difference in *Gs* is remarkably consistent regardless of relative percentile rank. This analysis also revealed that the difference for verbal abilities was also relatively even across the distribution, with males at the 10th percentile being an average of 3.0 standard score points above females at the 10th percentile, 3.0 points higher than females at the 50th percentile, and males at the 90th percentile were an

Table 7
WJ-R (1989) and WJ (1977): Male–female selected narrow abilities standard score by age level

WJ-R Variable		Age														
		5–6			7–9			10–13			14–18			19–34		
		Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS
	n:	222	204		446	425		488	503		484	514		188	245	
Cognitive Speed																
Visual	*M*:	97.5	100.7	−3.2	97.8	103.2	−5.5	97.9	106.1	−8.2	100.2	107.5	−7.3	94.5	102.9	−8.3
Matching	SD:	15.8	14.4		15.7	15.1		14.7	16.0		16.8	15.7		16.5	14.6	
Cross Out	*M*:	95.6	101.1	−5.5	97.3	102.4	−5.1	98.1	105.5	−7.4	98.1	104.0	−5.9	94.0	100.2	−6.2
	SD:	19.7	15.3		16.7	15.7		14.2	14.7		16.5	15.3		17.7	15.1	
Achievement Speed																
Writing	*M*:	100.3	102.0	−1.8	98.5	105.6	−7.0	96.4	104.8	−8.4	98.0	104.9	−6.9	92.5	99.5	−7.0
Fluency	SD:	12.5	12.5		14.0	14.0		14.5	15.2		16.5	16.8		15.9	15.3	

WJ-R Variable		Age											
		35–49			50–79			College[a]			Total		
		Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male S	Female SS	M–F SS
	n:	147	199		228	289		454	396		2657	2775	
Cognitive Speed													
Visual	*M*:	99.4	102.7	−3.3	99.1	106.1	−7.0	103.6	106.8	−3.1	99.2	105.1	−5.9
Matching	SD:	16.3	14.7		17.6	17.6		15.3	15.6		16.1	15.7	
Cross Out	*M*:	97.3	100.1	−2.8	98.7	103.5	−4.8	102.7	104.1	−1.3	98.3	103.2	−4.9
	SD:	16.4	13.5		18.2	16.6		14.8	14.6		16.5	15.2	
Achievement Speed													
Writing	*M*:	97.8	104.0	−6.3	98.3	105.7	−7.4	103.1	106.1	−3.0	98.5	104.5	−6.0
Fluency	SD:	16.3	15.7		16.2	15.9		10.8	12.4		14.7	15.0	

WJ-77 Variable		Age														
		5–6			7–9			10–13			14–18			19–34		
		Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS
	n:	333	344		458	529		582	688		405	471		63	72	
Cognitive Speed																
Visual	*M*:	97.0	101.9	−4.9	97.1	101.7	−4.6	97.0	101.9	−5.0	97.3	101.7	−4.4	95.8	102.8	−7.0
Matching	SD:	15.9	13.7		14.4	14.8		14.8	14.7		14.7	14.9		13.7	14.8	
Spatial	*M*:	97.3	101.7	−4.4	98.7	100.7	−2.0	97.9	101.1	−3.2	99.2	100.1	−1.0	98.5	100.9	−2.5
Relations	SD:	16.0	13.7		13.6	15.0		14.9	14.7		14.3	15.4		15.1	15.5	

WJ-77 Variable		Age								
		35–49			50–79			Total		
		Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS
	n:	52	62		71	95		1964	2261	
Cognitive Speed										
Visual	*M*:	99.8	101.8	−2.1	95.4	103.0	−7.6	97.0	101.9	−4.8
Matching	SD:	14.7	16.3		13.2	13.5		14.8	14.6	

(continued on next page)

Table 7 (*continued*)

WJ-R Variable		Age														
		5–6			7–9			10–13			14–18			19–34		
		Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS	Male SS	Female SS	M–F SS
Spatial	*M*:	101.7	99.8	1.9	95.8	102.2	−6.4	98.3	100.9	−2.6						
Relations	SD:	13.9	14.8		14.7	14.1		14.7	14.8							

Mean differences computed prior to rounding.
[a] 17–34 years of age.

average of 1.0 standard score points higher than females at the 90th percentile. Similar consistent differences across deciles were not evident in the other cognitive abilities tested. These results are presented in Table 9.

2.20. Correlational analysis of the relationship between Gs and speeded achievement measures

An additional follow-up analysis was completed in order to examine the degree of association between *Gs* and both speeded and nonspeeded measures of academic achievement. Given the results of the comparisons among means tests, one could hypothesize that the relationship between *Gs* and speeded tests would be stronger in both the general standardization sample and in the high school cohort. The results of the correlational analysis support this view. In the broad standardization sample, the correlations between *Gs* and Reading (0.37), Math (0.37) and Writing (0.38) are lower than the correlations observed for speeded achievement: 0.54 for Reading Fluency, 0.57 for Math Fluency and 0.49 for Writing Fluency. Thus, *Gs* accounts for 29.2%, 32.4% and 24.0% of the variance in the speeded measures as compared to 13.6%, 13.6% and 14.4% in nonspeeded measures of Reading, Math and Writing. Similar associations were observed in the High School Cohort, with Speeded correlations of 0.60, 0.56 and 0.51 as compared to nonspeeded correlations of 0.37, 0.30 and 0.37 for Reading, Math and Writing respectively. This corresponds to 36.0%, 31.4%, and 26.0% variance predicted in speeded achievement tests and a more modest 13.7%, 9.0% and 13.7% in the nonspeeded tests for the high school cohort. Similar correlations were observed in this cohort in speeded achievement tests for males (0.55, 0.52, and 0.52) and females (0.62, 0.59, and 0.48) and for nonspeeded tests (0.34, 0.32, and 0.31 for males and 0.41, 0.29 and 0.38 for females). This suggests that despite the observed mean sex differences in *Gs*, the relative association between *Gs* and speeded and nonspeeded achievement tests is relatively consistent. Finally, as predicted, the strength of this association is consistently greater in speeded tests than in nonspeeded tests.

Table 8
Male–female standard score differences across WJ III, WJ-R and WJ-77

Variable	Male–female Difference in Total Samples		
	WJ III	WJ-R	WJ-77
Male, Female (*n*)	885, 1102	2014, 2239	1964, 2261
General Intellectual Ability	−0.5	−2.5	−0.7
Broad CHC Abilities			
Verbal Ability (*Gc*)	1.9*	1.6	1.7
Long-Term Retrieval (*Glr*)	−1.2	−1.3	−2.3
Visual-Spatial Thinking (*Gv*)	−1.5	−3.2*	–
Auditory Processing (*Ga*)	−1.0	−2.4*	−2.7*
Fluid Reasoning (*Gf*)	−0.2	−1.3	−0.9
Processing Speed (*Gs*)	−5.3*	−6.8*	−3.8*
Short-Term Memory(*Gsm*)	0.7	−1.1	−0.6
Achievement			
Reading (*Grw*)	−1.1	−2.6*	−1.8
Math (*Gq*)	1.1	0.6	0.5
Writing (*Grw*)	−4.0*	−6.2*	−4.9*
Academic Knowledge (*Gc*)	2.8*	1.5	3.0*
Male, Female *n*:	1122, 1379	2657, 2775	1964, 2261
Cognitive Speed Tests			
Visual Matching	−4.0*	−5.9*	−4.8*
Decision Speed	−3.9*	–	–
Retrieval Fluency	−3.6*	–	–
Rapid Picture Naming	−3.0*	–	–
Cross Out	−2.0	−4.9*	–
Spatial Relations	–	–	−2.6
Achievement Speed Tests			
Reading Fluency	−5.0*	–	–
Math Fluency	−1.7	–	–
Writing Fluency	−7.1*	−6.0*	–

3. Discussion

Although there was some variation in main effects for sex differences across instruments (e.g. a main effect for visual spatial abilities in the WJ-R data, but not in the WJ III), the results for processing speed (*Gs*) are remarkably similar and robust: Males were significantly lower than females across WJ III, WJ-R, and WJ-77 and

Table 9
WJ III (2001): Male–female broad abilities standard score difference distribution across selected percentile ranks

Variable	WJ III Male–female standard score differences							
	Mean Difference	Selected Ability Percentiles						
		P05	P10	P25	P50	P75	P90	P95
General Intellectual Ability (Ext)	−0.5	0.0	1.0	0.0	−1.0	−1.0	0.0	−0.1
Broad CHC Abilities								
Verbal Ability (*Gc*)	1.9	3.0	3.0	2.0	3.0	1.0	1.0	3.0
Long-Term Retrieval (*Glr*)	−1.2	0.0	−1.0	−1.0	−1.0	−2.0	−2.0	−3.0
Visual-Spatial Thinking (*Gv*)	−1.5	−2.0	−1.0	0.0	−2.0	−4.0	−2.0	−3.0
Auditory Processing (*Ga*)	−1.0	−3.0	−2.0	−1.0	−1.0	−1.0	0.0	−0.8
Fluid Reasoning (*Gf*)	−0.2	−1.0	0.0	−1.0	−1.0	0.3	0.0	2.0
Processing Speed (*Gs*)	−5.3	−6.0	−6.0	−5.0	−5.0	−5.0	−7.0	−6.4
Short-Term Memory (*Gsm*)	0.7	2.0	0.0	0.0	1.0	1.0	2.0	4.0
Achievement								
Reading (*Grw*)	−1.1	−1.4	−1.5	−1.5	−0.5	−1.5	−0.2	1.6
Math (*Gq*)	1.1	0.0	0.0	0.5	1.5	1.1	1.5	2.9
Writing (*Grw*)	−4.0	−4.0	−4.5	−3.0	−3.0	−4.0	−5.0	−5.0
Academic Knowledge (*Gc*)	2.8	−0.5	1.0	2.0	3.0	3.2	3.0	4.0

across kindergarten, elementary, middle, and high school cohorts. This difference initially is negligible in the kindergarten data but increases in each cohort through high school.

A secondary, less robust, but consistent result was the higher performance for *Gc* (verbal abilities) for males. Although there is an evidently widely held view that females display language skills that are, on average, higher than males during development, this has not been evident in data-driven studies for vocabulary (Fenson, 1992). However, it is perhaps unexpected that there would be a consistent difference favoring males. Interestingly, one of the most consistent male–female differences in preschool language development relates to the average length of sentences used expressively with females using longer sentences, but the findings for other language abilities such as those examined in this paper have been much less consistent (Hyde & McKinley, 1997).

The results indicate that processing speed (*Gs*) is higher in females. Within the context of Carroll–Horn–Cattell (CHC) Theory, processing speed (*Gs*) is defined as the ability to automatically perform cognitive tasks when under pressure to maintain attention and concentration (Flanagan, McGrew, & Ortiz, 2000). Similarly, Carroll (1993) identifies *Gs* as the factor that measures speed of cognitive performance (see Carroll p. 613). Horn (1991) states *Gs* "…is measured most purely by tests that require rapid scanning and responding to intellectually simple tasks that almost all people would get right if the task were not highly speeded" (p. 215). Horn also notes in his discussion of *Gs* that "Speediness in scanning, inspecting and becoming aware of the salient features of problems is a pervasive source of individual differences in cognitive tasks" (p. 222). Finally, McGrew and Flanagan (1998) indicate that *Gs* is "typically measured by fixed interval timed tasks that require little in the way of complex thinking or mental processing" (p. 24). The *Gs* factor is considered as distinct from another type of speed measure, reaction time. Rather than speed of scanning and detecting salient features, reaction time (*Gt*) is defined as "the individual's quickness in reacting, or making decisions (McGrew & Flanagan, 1998, p. 24). Note that the decisions made in such tasks are relatively simple and are not designed to tax reasoning. Moreover, it is important to bear in mind that the results of this study do *not* provide evidence that boys are slower than girls with regard to reaction time, which is classified as a *Gt* ability. Rather, the observed significant difference in *Gs* indicates that males perform significantly lower than females on timed tasks involving relatively simply information. That is, males perform worse than females when there is pressure to maintain attention and concentration (in the sense that Carroll, 1993, defined *Gs*). The processing speed difference in males and females leads to speculation about the source of this contrast. The WJ III includes Rapid Picture Naming, Visual Matching, Decision Speed, and Cross Out as qualitatively different narrow ability tests to estimate *Gs*. These are timed and require linguistic knowledge (Rapid Picture Naming), matching (Visual Matching, Cross Out) or a combination of linguistic knowledge and matching (Decision Speed) so that diverse cognitive abilities are sampled for information about processing speed and all are relatively simple tasks. With the exception of the 50–79 year old group, wherein males displayed slight advantages over females in Decision Speed, Rapid Picture Naming, and Cross Out (but not Visual Matching or Retrieval Fluency, which favored females), there was a remarkably consistent female advantage for narrow abilities across cohorts. Because the sex difference for *Gs* was relatively consistent across these narrow abilities, it appears that the male–female disparity in processing speed cannot be accounted for on the basis of distinctions in the overall linguistic or spatial abilities of the males and females in the sample.

Kail (1990, 2003) has long argued that processing speed is a general cognitive property that relates to diverse aspects of general intellectual ability. The data herein suggest that processing speed, in terms of sex differences, does indeed transcend diverse mental abilities, lending support to Kail's position. It is important to bear in mind that the sex difference finding for *Gs* does not conflict with Kail's contention that processing speed relates to GIA. In the case of the WJ III, *Gs* correlates 0.62 with GIA, which supports a model of *Gs* as a reasonable predictor of GIA. The finding that females are consistently higher than males for *Gs* but not different for GIA is not counter-evidence for this view. That is, because the overall GIA was not different across sex, and indeed, was quite similar in males and females, it appears that males are somehow compensating for the general difference in *Gs*. One aspect of this may be the observed advantage in verbal abilities (*Gc*), but this could account for only about 50% of the processing speed gap. Additional slight advantages were observed in short-term memory and academic knowledge (which relates to *Gc*), but the nature and extent of potential compensatory abilities should be explored in more detail in future studies. It is possible that a combination of sex related lower performance in processing speed coupled with a deficit in verbal ability or even coupled with no compensatory increase in verbal ability results in the weaknesses observed in learning disabilities.

Interestingly, with the exception of response latency in spatial ability (e.g., Kail, Carter, & Pellegrino, 1979), there has not been a substantial literature on sex differences in processing speed as related to general intellectual ability. However, Jensen (1998) reported under "smaller group factors," sex differences favoring females in "speed and accuracy" with *d* values ranging from 0.20 to 0.30. Interestingly, Jensen also reports a *d* value of 0.84 in 12th graders taking the General Aptitude Test Battery in "clerical perception," which he suggests relates to perceptual speed and accuracy. Although Jensen offered no further discussion of these data, it is striking that the magnitude of the *d* value herein for the high school cohort is quite similar to that in the report on 12th grader performance on clerical perception, leading us to speculate that this earlier report does indeed relate to *Gs* as Jensen proposed.

3.1. Academic implications

The sex difference in processing speed would appear to have important academic implications. The results of this study indicate that GIA is not different in males and females, but the speed (processing speed) at which this knowledge can be displayed and manipulated in routine tasks is significantly different. This finding directly relates to timed tasks or narrow abilities that involve processing speed on relatively unfamiliar information. For example, reading and writing fluency were significantly lower in males in the data from achievement testing, a difference that is likely related, at least in part, to the processing speed difference. Consider that many classroom activities, including testing, are directly or indirectly related to processing speed. The higher performance in females may contribute to a classroom culture that favors females, not because of teacher bias (Hoff-Sommers, 1998) but because of inherent sex differences in processing speed and the relationship this parameter has with classroom activities and potential learning differences in males and females.

3.2. Directions for future research

It is important to bear in mind that the sex differences herein are relatively large in terms of magnitude and in terms of statistical significance. But, there is, of course, extensive overlap in the *Gs* distributions of males and females. Because of this, direct clinical implications must await further study on clinical populations. However, several aspects of these findings point to future research. First, the similar male and female means for GIA indicates that overall cognitive abilities are not different. This is evident despite the relatively large difference in processing speed. This would suggest that males display relative strengths in other broad and narrow abilities that compensate for the overall difference in processing speed. The study of these compensatory strategies may yield useful information for teaching clinical populations. In addition, the practical applications of this finding should be examined as well. That is, should teaching methods take into account this processing speed difference in males and females? One could speculate that males would fare better in teaching activities that are untimed (as compared to timed), and that overall estimates of learning potential should take measures of processing speed into consideration.

From a neuro-psychological perspective, the strong sex differences in processing speed, particularly through early adolescence suggest intriguing possibilities for understanding the developmental and neurological bases of these differences. For example, Benes, Turtle, Khan, and Farol, (1994) and Benes (1998) reported sex differences in myelinization ratio of male in female superior medullary lamina (SML): "When the data were broken down according to gender, male and female subjects showed no differences between 0 and 5 years of age, however, for female subjects, the myelin ratio was 41% higher at 6 to 11 years of age (F=9.32, p=0. 005), 33% higher at 12–19 years of age (F=6.95, p=0. 01), and 23% higher at 20–29 years of age (F=4.66, p=0. 04). Thereafter, no significant difference was noted between the genders (p. 480, Benes et al., 1994)." Benes et al discussed this sex difference in terms of behavioral sex differences in emotional regulation, a function associated with the SML region. One wonders whether similar differential myelinization rates in neural regions associated with processing speed may relate to the observed patterns of developmental sex differences. There were increasing differences through adolescence and then the sex difference narrowed considerably in early adulthood. A well-articulated neuro-psychology of processing speed, in terms of cerebral regions activated and integration of these sites would be useful for interpreting the observed sex difference in processing speed. At this time, there does not appear to be any suggestion that the hippocampus, site of the sex difference in myelinization in the Benes report, is implicated in processing speed, but coordinated neuroimaging studies are needed to investigate this issue. Finally, the clinical ramifications of these findings should be examined. Current special education and clinical practice often does not include estimates of processing speed. However, the impact of this broad ability may be important and informative. Future research should focus on evaluation of processing speed in clinical populations such as ADHD, autism, learning disabilities, reading problems, and other special populations to examine the relationship between deficits in achievement and other performance measures and estimates of *Gs*. It is possible that a major part of the sex discrepancy in clinical and special education placements may be directly or indirectly related to sex differences in processing speed.

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