

## THE RELATIVE CONTRIBUTIONS OF THE CATTELL-HORN-CARROLL COGNITIVE ABILITIES IN EXPLAINING WRITING ACHIEVEMENT DURING CHILDHOOD AND ADOLESCENCE

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This study examined the relative contributions of measures of Cattell-Horn-Carroll (CHC) cognitive abilities in explaining writing achievement. Drawing from samples that covered the age range of 7 to 18 years, simultaneous multiple regression was used to regress scores from the Woodcock-Johnson III (WJ III; Woodcock, McGrew, & Mather, 2001) that represent CHC broad and narrow abilities onto the WJ III Basic Writing Skills and Written Expression cluster scores. At most age levels, Comprehension-Knowledge demonstrated moderate to strong effects on both writing clusters, Processing Speed demonstrated moderate effects on Basic Writing Skills and moderate to strong effects on Written Expression, and Short-Term Memory demonstrated moderate effects. At the youngest age levels, Long-Term Retrieval demonstrated moderate to strong effects on Basic Writing Skills and moderate effects on Written Expression. Auditory Processing, and Phonemic Awareness demonstrated moderate effects on only Written Expression at the youngest age levels and at some of the oldest age levels. Fluid Reasoning demonstrated moderate effects on both writing clusters only during some of the oldest age levels. Visual-Spatial Thinking primarily demonstrated negligible effects. The results provide insights into the cognitive abilities most important for understanding the writing skills of children during the school-age years. © 2008 Wiley Periodicals, Inc.

During the past decade, many test authors and publishers drew from research supporting the Cattell-Horn-Carroll (CHC) theory to guide the revisions of prominent intelligence test batteries (see Alfonso, Flanagan, & Radwan, 2005). CHC theory stems most directly from extended Gf-Gc theory (e.g., Horn & Blankson, 2005) and from the three-stratum theory (Carroll, 1993; see McGrew, 2005). Both theories direct those who use intelligence test batteries toward assessment of a number of semi-independent, broad or stratum II abilities. In extended Gf-Gc theory, these abilities include Acculturation Knowledge, Fluid Reasoning, Short-Term Apprehension and Retrieval or Short-Term Memory, Fluency of Retrieval from Long-Term Storage or Long-Term Memory, Processing Speed, Visual-Spatial Thinking, Auditory Processing, and Quantitative Knowledge. In the three-stratum theory, they include Crystallized Intelligence, Fluid Intelligence, General Memory and Learning, Broad Retrieval Ability, Broad Cognitive Speediness, Broad Visual Perception, Broad Auditory Perception, and Processing Speed/Decision Speed.

Recently published test batteries that have drawn on CHC theory include the Woodcock-Johnson III (WJ III) Tests of Cognitive Abilities (Woodcock, McGrew, & Mather, 2001); the Stanford-Binet Intelligence Scale, Fifth Edition (Roid, 2003); the Kaufman Assessment Battery for Children, Second Edition (Kaufman & Kaufman, 2004); and the Differential Ability Scales, Second Edition (Elliott, 2006). The publication of these theory-based test batteries has provided the means to operationalize a number of broad abilities at the composite level. The focus on theory-based part scores at the

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composite level has been purported to overcome many of the limitations of interpreting atheoretical subtest scores with low reliability as representing specific cognitive abilities (Flanagan & Kaufman, 2004; Kaufman & Lichtenberger, 2006).

### *Woodcock-Johnson III Reading and Mathematics Research*

Using the first test battery published based on CHC theory, the WJ III Tests of Cognitive Abilities (Woodcock et al., 2001), a number of researchers have used composite scores representing CHC broad abilities to better understand their contributions to reading and mathematics. For example, in the area of reading, Evans, Floyd, McGrew, and LeForgee (2002) examined the relative contributions of the WJ III CHC factor clusters to the prediction of measures of reading decoding skills and reading comprehension. They found that the Comprehension-Knowledge cluster demonstrated strong effects on both reading domains across childhood and adolescence. The Short-Term Memory, Auditory Processing, Processing Speed, and Long-Term Retrieval clusters demonstrated moderate effects on the reading domains during the elementary school years. Floyd, Bergeron, and Alfonso (2006) examined the differences in the cognitive ability profiles (including WJ III clusters) of children with specific normative deficits in reading comprehension; children with average reading comprehension, reading decoding skills, and mathematics; and children with normative deficits across all three domains. Results revealed that the poor comprehenders scored significantly lower than the average-achieving group across all measures, but the poor comprehenders were most discrepant from the average-achieving group and from the normative mean on measures of language- and knowledge-based abilities, such as Comprehension-Knowledge. In contrast, the poor comprehenders scored significantly higher than the low achievement group on all clusters except for Visual-Spatial Thinking and Phonemic Awareness.

In the area of mathematics, Floyd, Evans, and McGrew (2003) examined the relative contributions of the WJ III CHC factor clusters to the prediction of mathematic calculation skills and mathematics reasoning. Like Evans et al. (2002), they found that the Comprehension-Knowledge, Short-Term Memory, and Processing Speed clusters typically demonstrated at least moderate effects on the mathematics domains across most age levels. The Long-Term Retrieval and Auditory Processing clusters demonstrated moderate effects on the mathematics domains only during the earliest ages of the analysis. In contrast to Evans et al. (2002), the Fluid Reasoning cluster demonstrated moderate relations with the mathematics domains. Another study by Proctor, Floyd, and Shaver (2005) targeted the cognitive profiles of two types of children with low mathematics achievement: those with specific normative deficits in mathematics calculation and those with specific normative deficits in mathematics reasoning. Across the WJ III CHC factor clusters, children with deficits in mathematics calculation did not perform significantly lower than an average-achieving group. However, children with deficits in mathematics reasoning scored significantly lower than an average-achieving group on the Fluid Reasoning and Comprehension-Knowledge clusters.

### *Writing Achievement*

There appear to have been few published studies examining the effects of the CHC broad abilities or narrow abilities on writing achievement, and there have been no such published studies to date employing composites from the four recently published test batteries based on CHC theory to examine these effects. Using the previous edition of the WJ III, the Woodcock-Johnson Psycho-Educational Battery-Revised (WJ-R; Woodcock & Johnson, 1989), McGrew and Knopik (1993) examined the relative contribution of the seven WJ-R *Gf-Gc* clusters to the prediction of basic writing skills and written expression across the lifespan. The WJ-R Comprehension-Knowledge cluster demonstrated the strongest effects on the writing domains at all age levels after age

7 years, and the strength of its effects increased with age. The Processing Speed cluster demonstrated consistent and significant effects on the writing domains across the lifespan. The Auditory Processing cluster demonstrated consistent and significant effects on the writing domains until approximately age 11 years. The Fluid Reasoning cluster also displayed significant effects on the writing domains during the early school-age years. The Long-Term Retrieval, Short-Term Memory, and Visual-Spatial Thinking<sup>1</sup> clusters demonstrated no consistent effects on the writing domains. Hale, Fiorello, Kavanagh, Hoepfner, and Gaither (2001) also reported that, when commonality analyses organized according to CHC theory were applied to the Wechsler Intelligence Scale for Children, Third Edition (Wechsler, 1991) Full Scale and factor scores, a number of significant relations between CHC broad abilities and spelling as well as written language were apparent above and beyond the effects associated with the Full Scale IQ. These abilities were Crystallized Intelligence, Quantitative Knowledge, and Short-Term Memory.

### *Purpose of Study*

The two studies reviewed previously provide validity evidence focusing on the external relations between measures of the CHC cognitive abilities and writing achievement. However, at present, there is a need to expand the understanding of these effects on writing achievement using more recently developed measures of CHC broad abilities and narrow abilities. This study replicates and extends the prior studies examining the relative contributions of CHC cognitive abilities to writing skill development.

## METHOD

### *Participants*

Participants were drawn from the nationally representative norming sample of the WJ III (Woodcock et al., 2001). From this larger sample, only participants who completed all of the WJ III tests needed to obtain the necessary measures used in this study were included. These participants were divided into 12 age-based samples representing 1 year of age starting at age 7 years and continuing through age 18 years. Although age groups ranging from 6 to 19 years were targeted for inclusion, samples for age 6 and age 19 years were omitted from further analysis because they included less than 111 participants. One rule of thumb suggests that, when examining individual predictors using multiple regression, the sample size should be greater than or equal to 104 plus the number of independent variables (7 in these analyses; Green, 1991).

As evident in Table 1, age-based samples ranged in size from 114 to 224 participants. Table 1 presents the percentages of children from each gender and from each race and ethnicity for each sample. A series of chi-square tests of independence revealed that no age-based sample differed significantly across these demographic variables from its corresponding age-based sample that included children from the WJ III norming sample excluded from this study due to missing data (using  $p = .004$  [.05 with Bonferroni correction] for each of the 12 analyses).

### *Measures*

*Writing Clusters.* Four tests from the WJ III Tests of Achievement (Woodcock et al., 2001) were used to form two writing clusters. The WJ III tests (a) Spelling and (b) Punctuation and Capitalization yield the Basic Writing Skills cluster, which represents knowledge of spelling, punctuation,

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<sup>1</sup> The name for the Visual-Spatial Thinking cluster on the WJ-R was Visual Processing. For consistency, the WJ III cluster name is used for this WJ-R cluster.

Table 1  
*Percentages of Gender, Race, and Ethnicity of Participants for 12 Age Groups*

Age group	<i>n</i>	Gender		Race and ethnicity				
		M	F	W	B	AI	API	H
7	138	52.2	47.8	72.5	14.5	6.5	6.5	8.7
8	193	49.7	50.3	78.8	14.0	3.6	3.6	8.8
9	199	40.7	59.3	77.4	14.1	3.0	5.5	6.5
10	224	51.8	48.2	81.3	11.6	1.3	5.8	10.3
11	179	53.1	46.9	76.0	19.6	2.2	2.2	6.1
12	142	54.9	45.1	76.1	12.7	2.8	8.5	12.0
13	132	51.5	48.5	82.6	12.1	3.0	2.3	6.8
14	136	49.3	50.7	72.1	18.4	1.5	8.1	11.0
15	136	59.6	40.4	76.5	17.6	0.7	5.1	8.1
16	127	52.8	47.2	78.0	15.7	0.8	5.5	7.1
17	114	54.4	45.6	79.8	14.9	2.6	2.6	7.0
18	119	47.1	52.9	83.2	12.6	0.8	3.4	4.2

*Note.* M = Male, F = Female, W = White, B = Black, AI = American Indian, API = Asian and Pacific Islander, H = Hispanic.

and capitalization rules. Spelling requiring examinees to write correct spellings of orally dictated words, whereas Punctuation and Capitalization requires them to use correct punctuation and capitalization in response to oral directives. The WJ III tests Writing Samples and Writing Fluency yield the Written Expression cluster, which represents compositional fluency and compositional accuracy. Writing Samples requires examinees to write sentences in response to a variety of demands, and sentences are evaluated with respect to the quality of expression. Writing Fluency requires examinees to generate simple sentences quickly in response to word and picture cues during a 7-minute task. Basic Writing Skills has demonstrated a median reliability coefficient of .94 across ages 7 to 18 years, and Written Expression has demonstrated a median reliability coefficient of .90 across this period (McGrew & Woodcock, 2001).<sup>2</sup> Correlations between the writing clusters and composites from the Kaufman Test of Educational Achievement (Kaufman & Kaufman, 1985) and the Wechsler Individual Achievement Test (Wechsler, 1992) provide validity evidence (McGrew & Woodcock, 2001).

*Cognitive Clusters.* The seven WJ III CHC factor clusters were used to represent CHC broad abilities (Woodcock et al., 2001). One WJ III clinical cluster, Phonemic Awareness, was used to represent the CHC narrow ability Phonetic Coding. Two tests yield each of the seven CHC factor clusters and the Phonemic Awareness cluster. Median reliability coefficients for each cluster across ages 7 to 18 years are as follows: Comprehension-Knowledge, .95; Long-Term Retrieval, .88; Visual-Spatial Thinking, .79; Auditory Processing, .89; Fluid Reasoning, .95; Processing Speed, .92; Short-Term Memory, .87; and Phonemic Awareness, .88 (McGrew & Woodcock, 2001). Substantial validity evidence for the CHC factor clusters and the Phonemic Awareness clusters is presented in McGrew and Woodcock (2001).

<sup>2</sup> Rasch analysis was used to calculate the reliability of speeded tests and tests that employed multiple-point scored items. Split-half procedures were used for the remaining tests. Cluster reliabilities were calculated based on the obtained reliabilities for their component tests.

Table 2  
*Means and Standard Deviations for W-Scores for the Writing Achievement Clusters, the CHC Factor Clusters, and the Phonemic Awareness Cluster for 12 Age Groups*

WJ III score	Age group											
	7	8	9	10	11	12	13	14	15	16	17	18
BWS	469.3 (20.0)	485.0 (18.6)	494.9 (17.1)	505.7 (19.3)	511.5 (17.1)	517.6 (18.0)	521.5 (15.8)	527.0 (16.0)	526.6 (18.9)	534.0 (16.0)	534.2 (18.3)	538.0 (17.3)
WE	481.1 (9.6)	491.4 (10.4)	497.6 (9.5)	501.6 (10.8)	506.5 (9.5)	510.6 (10.7)	514.9 (10.5)	518.9 (9.4)	519.2 (10.6)	522.6 (9.4)	523.4 (10.5)	524.9 (10.8)
Glr	496.0 (4.3)	497.9 (4.4)	500.1 (4.9)	501.2 (4.8)	502.4 (4.4)	504.0 (4.9)	504.2 (5.1)	506.2 (5.8)	506.1 (5.0)	507.0 (5.6)	507.5 (5.0)	508.0 (5.8)
Ga	495.4 (7.4)	498.4 (7.9)	499.8 (8.0)	501.3 (8.4)	504.1 (7.9)	506.7 (9.4)	508.9 (9.4)	510.8 (9.7)	511.2 (10.6)	513.1 (9.8)	513.3 (10.7)	514.9 (9.4)
Gc	483.5 (11.0)	492.0 (11.9)	497.7 (12.7)	503.1 (13.1)	509.6 (13.8)	514.8 (13.3)	519.1 (14.4)	523.9 (15.0)	525.0 (16.3)	530.4 (12.6)	533.0 (13.8)	535.0 (14.4)
Gv	493.3 (7.4)	497.6 (7.2)	499.1 (8.0)	501.7 (8.1)	501.8 (7.5)	505.0 (8.6)	506.0 (9.0)	508.1 (9.7)	508.6 (8.6)	510.6 (8.2)	510.8 (8.4)	509.4 (9.8)
Gf	485.9 (16.3)	493.9 (14.5)	497.9 (12.8)	503.2 (14.0)	505.7 (13.9)	509.6 (14.6)	510.3 (14.0)	516.1 (15.4)	515.4 (13.5)	521.2 (13.3)	519.7 (13.4)	518.7 (14.5)
Gs	469.3 (14.9)	485.9 (14.0)	494.7 (15.3)	505.2 (16.5)	512.3 (13.8)	520.4 (16.5)	525.9 (17.4)	532.4 (17.0)	535.2 (18.5)	541.8 (19.2)	541.3 (18.4)	545.4 (20.4)
Gsm	486.0 (16.3)	494.9 (16.5)	497.8 (15.7)	503.3 (18.9)	509.8 (17.3)	513.9 (18.7)	516.6 (19.5)	521.0 (20.3)	523.9 (19.3)	526.0 (19.5)	525.9 (19.7)	530.1 (20.3)
PA	495.6 (9.0)	498.7 (8.8)	499.5 (9.0)	501.5 (9.7)	504.5 (8.6)	507.1 (9.7)	509.1 (10.1)	511.0 (10.0)	511.8 (11.0)	513.7 (10.6)	514.2 (11.4)	515.5 (9.9)

Note. Standard deviations are presented in parentheses.

BWS = Basic Writing Skills, WE = Written Expression, Glr = Long-Term Retrieval, Ga = Auditory Processing, Gc = Comprehension-Knowledge, Gv = Visual-Spatial Thinking, Gf = Fluid Reasoning, Gs = Processing Speed, Gsm = Short-Term Memory, PA = Phonemic Awareness.

### Analysis

The *W*-score was the metric of analysis. *W*-scores are transformations of raw scores into equal-interval units that are derived through application of the one-parameter item response theory or Rasch measurement model (Woodcock & Dahl, 1971). Each cluster *W*-score represents the arithmetic average of the *W*-scores of the tests composing the cluster. Table 2 presents the means and standard deviations of *W*-scores for each cluster and for each sample.

For the initial simultaneous (a.k.a., standard or forced-entry) multiple regression analyses, the predictor variables were the seven CHC factor clusters. In one model, the criterion variable was the Basic Writing Skills cluster, whereas in the other model, the criterion variable was the Written Expression cluster. In additional regression analyses, Phonemic Awareness was substituted for the CHC factor cluster Auditory Processing with each model.

For each cognitive cluster and each writing achievement cluster, 12 standardized regression coefficients (a.k.a., beta weights) were plotted on a graph with age representing the x-axis. Standardized regression coefficients indicate the proportion of standard deviation units that the criterion variable changes as a function of one standard deviation change in a predictor variable. Given that sampling error is present to an unknown degree in each age-differentiated sample, the best population estimates of the age-related changes between the cognitive clusters and the writing achievement clusters were identified through the application of the distance-weighted least squares smoothing function to the plot of the standardized regression coefficients (Wilkinson, 1990).

## RESULTS

To examine the representativeness of the age-based samples further, we examined the magnitude of the differences in the Basic Writing Skills cluster scores and Written Expression cluster scores for the samples included in this study when compared to those from children included in the WJ III norming sample but excluded from this study due to missing data. Independent-samples *t*-tests indicated that there were no significant differences at any age level for Basic Writing Skills and no significant differences for 16 of the 17 age levels for Written Expression (using  $p = .004$  [.05 with Bonferroni correction]). At age 7 years, the mean Written Expression *W*-score for the sample included in this study ( $M = 469.3$ ) was significantly higher than the mean *W*-score for those not included in this study ( $M = 459.2$ ),  $p < .001$ .

Preliminary data analyses were also conducted with each age-based sample to ensure that the assumptions of simultaneous multiple regression were not violated (Tabachnick & Fidell, 2007). Results revealed 38 univariate outliers (with  $p = .001$ , two-tailed test) across age groups, but for no variable were there more than two univariate outliers. Because the study used reasonably large samples, only six cases with extreme univariate outliers were deleted. Subsequent results revealed seven multivariate outliers (using Mahalanobis distance with  $p = .001$  for the  $\chi^2$  value) across age groups. These seven cases were also deleted. No variable was notably skewed (all values  $< |1.0|$  except one) at any age level. Although 15 variables demonstrated notable positive kurtosis (i.e., values  $> 1.0$ ) at some age level, no kurtosis was severe enough to affect our analyses with samples as large as we used (Waternaux, 1976). Review of residual scatterplots for each age level and each criterion variable revealed that the assumptions of normality, linearity, and homoscedasticity of errors of prediction and absence of residual outliers were met for all analyses in which the Basic Writing Skills was the criterion variable. However, the residual scatterplots for the analyses in which the Written Expression was the criterion variable revealed five residual outliers ( $p = .001$ ). These five cases were deleted. After another two cases with residual outliers were deleted, subsequent residual scatterplots indicated that the assumptions of normality, linearity, and homoscedasticity of errors of prediction and absence of residual outliers were met for all analyses.

Figures 1 through 4 present the results of the analyses. Each figure displays four lines representing the smoothed standardized regression coefficient values for two cognitive clusters that were used

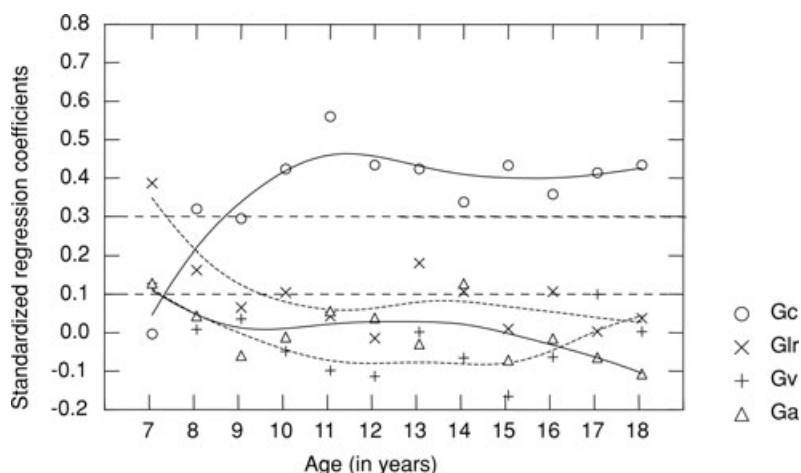


FIGURE 1. Standardized regression coefficients as a function of age for Comprehension-Knowledge, Long-Term Retrieval, Visual-Spatial Thinking, and Auditory Processing in predicting Basic Writing Skills. Gc = Comprehension-Knowledge, Glr = Long-Term Retrieval, Gv = Visual-Spatial Thinking, Ga = Auditory Processing.

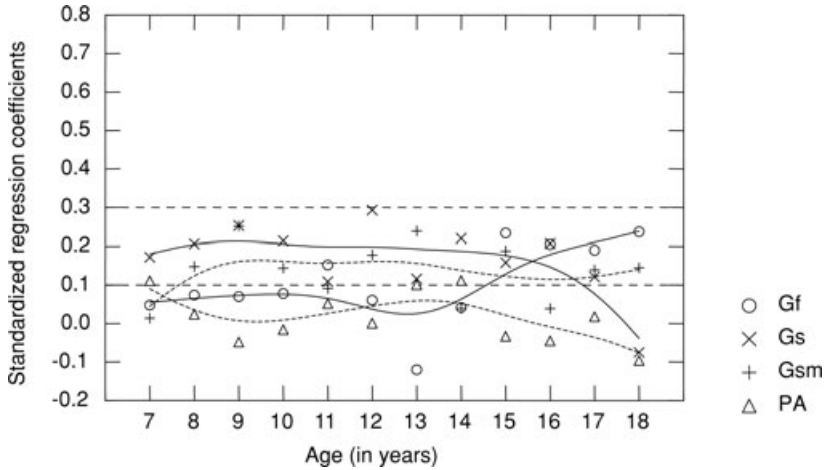


FIGURE 2. Standardized regression coefficients as a function of age for Fluid Reasoning, Processing Speed, Short-Term Memory, and Phonemic Awareness in predicting Basic Writing Skills. Gf = Fluid Reasoning, Gs = Processing Speed, Gsm = Short-Term Memory, PA = Phonemic Awareness.

as predictors of the Basic Writing Skills cluster and the Written Expression cluster. (For reference, the actual standardized regression coefficient values are represented by symbols according to the key for each figure.) Two parallel dashed lines that correspond to standardized regression coefficients of 0.10 and 0.30 are also presented in each figure. The lines are guides for interpreting the magnitude of the smoothed regression coefficient values and correspond to previously established rules of thumb (e.g., Evans et al., 2002; McGrew & Knopik, 1993). Thus, rather than focusing on the statistical significance of the standardized regression coefficients, these criteria operationally define practical significance to be associated with standardized regression coefficients of 0.10 or above.<sup>3</sup> Coefficients ranging from 0.10 to 0.29 are classified as representing *moderate* effects, whereas those 0.30 or above are classified as *strong* effects.<sup>4</sup>

### Basic Writing Skills

As evident in Figure 1, Comprehension-Knowledge demonstrated moderate to strong effects on Basic Writing Skills. The effects of Comprehension-Knowledge on Basic Writing Skills were moderate from age 7 to age 9 years, after which they were strong. Note that these effects plateau around age 11 years with standardized regression coefficients at approximately 0.4. Long-Term Retrieval demonstrated strong effect at age 7 years and moderate effects until age 10 years. In contrast, Visual-Spatial Thinking and Auditory Processing primarily demonstrated negligible effects. As evident in Figure 2, Fluid Reasoning demonstrated primarily negligible effects until age 15 years. Processing Speed demonstrated moderate effects from age 7 until age 17 years. Short-Term Memory demonstrated moderate effects throughout the period of analysis after age 7 years. Across age levels, squared multiple correlation coefficients ranged from .40 to .61 ( $Mdn = .46$ ). From

<sup>3</sup> Based on our sample sizes, standardized regression coefficients in the range of 0.15 or higher are statistically significant ( $p < .05$ ).

<sup>4</sup> These rules of thumb are similar to others for interpreting the effect sizes for influences on academic achievement. For example, according to Keith (2005), standardized regression coefficients that are less than 0.05 are *not meaningful*, those that are 0.05 and above are *small*, those above 0.10 are *moderate*, and those above 0.25 are *large*.

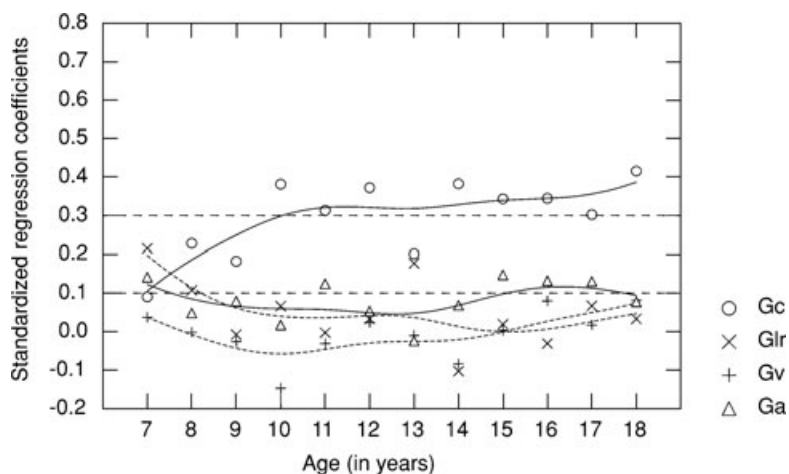


FIGURE 3. Standardized regression coefficients as a function of age for Comprehension-Knowledge, Long-Term Retrieval, Visual-Spatial Thinking, and Auditory Processing in predicting Written Expression. Gc = Comprehension-Knowledge, Glr = Long-Term Retrieval, Gv = Visual-Spatial Thinking, Ga = Auditory Processing.

the additional regression analyses in which Phonemic Awareness was substituted for Auditory Processing, Phonemic Awareness primarily demonstrated negligible effects. For these analyses, squared multiple correlation coefficients also ranged from 0.40 to 0.61 ( $Mdn = 0.46$ ).

#### Written Expression

Like with the Basic Writing Skills analyses, as evident in Figure 3, the effects of Comprehension-Knowledge on Written Expression were moderate until age 10 years and strong afterward. Its effects appear to plateau with standardized regression coefficients around 0.32. Long-Term Retrieval demonstrated moderate effects at ages 6 and 7 years, but its effects were negligible afterward. Whereas Visual-Spatial Thinking demonstrated only negligible effects, Auditory Processing demonstrated moderate effects at age 7 years and again in late adolescence (ages 16 and 17 years). As evident in Figure 4, Fluid Reasoning demonstrated mostly negligible effects, but some effects were moderate at ages 15 and 16 years. Processing Speed demonstrated moderate and strong effects across the period of analysis. Its effects were moderate at age 7 years and at ages 15 through 18 years, but from age 8 through 14 years, its effects were strong. Short-Term Memory demonstrated moderate effects after age 7 and until age 18 years. Across age levels, squared multiple correlation coefficients ranged from .28 to .61 ( $Mdn = .54$ ). Phonemic Awareness demonstrated mostly negligible effects in the additional regression analyses. However, its effects were moderate at age 7 years and again in late adolescence (ages 15 through 17 years). For these analyses, squared multiple correlation coefficients again ranged from .28 to .61 ( $Mdn = .54$ ).

#### DISCUSSION

This study contributes to an emerging body of model- and data-based knowledge regarding potentially important effects of CHC cognitive abilities on reading, writing, and mathematics.<sup>5</sup>

<sup>5</sup> The content of the discussion is organized by broad and narrow cognitive abilities, rather than by age group or by writing achievement domain. However, a figure presenting the major findings of this study organized by age group and writing achievement domain can be obtained from the first author or from visiting <http://psyc.memphis.edu/people/faculty/floyd.shtml>



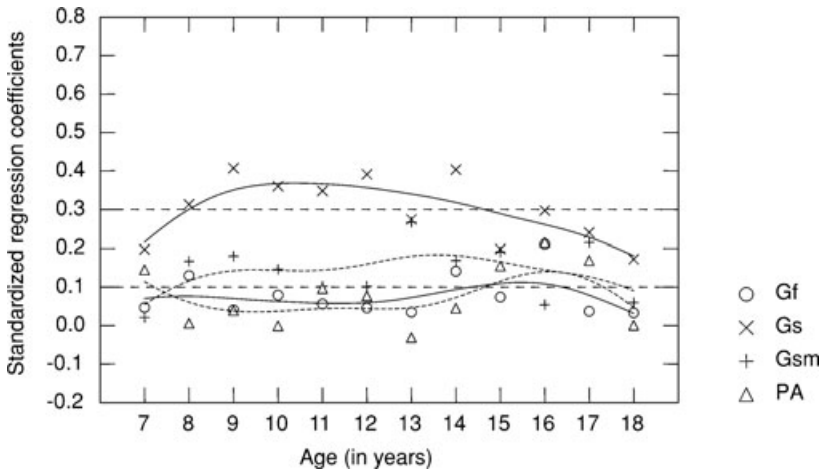


FIGURE 4. Standardized regression coefficients as a function of age for Fluid Reasoning, Processing Speed, Short-Term Memory, and Phonemic Awareness in predicting Written Expression. Gf = Fluid Reasoning, Gs = Processing Speed, Gsm = Short-Term Memory, PA = Phonemic Awareness.

### *Comprehension-Knowledge*

Consistent with prior research guided by CHC theory that focused on writing and similar research targeting reading and mathematics, it was not surprising that Comprehension-Knowledge was often the strongest and most consistent predictor of writing achievement across childhood and adolescence and that its strongest effects began as children enter upper elementary school (about age 10 years). It is logical that vocabulary knowledge and world knowledge would be highly related to knowledge of spelling, punctuation, and capitalization rules, as reflected in the basic writing skills analysis. In addition, these findings are consistent with research demonstrating a strong link between verbal ability, verbal reasoning, or oral language skills and compositional quality (e.g., Abbott & Berninger, 1993), as reflected in the written expression analysis. Consistent with some theoretical models of the writing process (e.g., Berninger, 1999; Hayes & Flower, 1980), vocabulary knowledge and knowledge of the domain on which writing is focused form the foundation of writing itself.

### *Processing Speed*

Processing Speed demonstrated at least moderate effects with both basic writing skills and written expression throughout most of childhood and adolescence. These findings are consistent with those from McGrew and Knopik (1993) that focused on writing and with those from Floyd et al. (2003) that focused on mathematics. The effects of Processing Speed were strongest in the written expression analysis. Processing Speed is believed to be important to written expression because the more rapidly an individual can automatize basic skills, the more attention and memory resources can be allocated to higher-level aspects of task performance. For example, compositional quality is enhanced if the writer has the attentional resources to monitor what has been written and the memory resources to retrieve relevant information from long-term stores while writing.

### *Short-Term Memory*

Short-Term Memory demonstrated moderate effects on both basic writing skills and written expression after the earliest ages of the analysis. These findings are consistent with those from Hale et al. (2001) but inconsistent with those from McGrew and Knopik (1993). A body of research and

a number of writing theories indicating the importance of the management of verbal information and the use of writing strategies via a limited-capacity and temporally constrained memory system while writing. These operations are believed to be facilitated by a central executive that allocates attention and strategic resources (Berninger, 1999; Swanson & Berninger, 1996). Although such memory abilities have often not been found to be important for spelling, punctuation, and capitalization performance, the findings of this study are generally consistent with others examining the effects of verbal working memory on compositional fluency and compositional accuracy (Berninger, Carwright, Yates, Swanson, & Abbott, 1994; Berninger, Whitaker, Feng, Swanson, & Abbott, 1996; Swanson & Berninger, 1996).

### *Long-Term Retrieval*

Although previous research organized according to CHC theory did not indicate the relative importance of Long-Term Retrieval to writing (McGrew & Knopik, 1993), this ability demonstrated strong to moderate effects on basic writing skills and moderate effects on written expression during only the early elementary grades. Perhaps this finding is not surprising for a number of reasons. First, the WJ III Long-Term Retrieval cluster taps into abilities associated with rapid automatic naming, which have shown to add significant predictive power in explaining some writing skills (e.g., Savage, Frederickson, Goodwin, Smith, & Tuersley, 2005). In addition, consistent with theoretical models of writing (e.g., Berninger, 1999), the early development of writing requires fluent retrieval of knowledge of spelling, punctuation, and capitalization rules, as well as writing strategies, from long-term memory stores. Such theoretical models also explain why the memory retrieval processes decline in relative importance with accumulating writing experience, whereas vocabulary knowledge and world knowledge (as measured by Comprehension-Knowledge) increase in relative importance.

### *Auditory Processing and Phonemic Awareness*

Based on research by McGrew and Knopik (1993), it was unexpected that both the Auditory Processing and Phonemic Awareness clusters would demonstrate typically negligible effects on basic writing skills and moderate effects on written expression at only age 7 years and in late adolescence. Although the predictors (the WJ-R Auditory Processing cluster and the WJ III Phonemic Awareness cluster) are similar in design, it may be that other WJ III cognitive clusters are now accounting for relatively more writing achievement variance than in the previous research. As a result, these clusters now explain a narrower portion of writing achievement when considered simultaneously with other cognitive abilities. Alternately, real changes may have occurred in the environmental experiences (possibly instructional ones) for school-age children during the past decade that have diminished the effects of auditory processing and phonemic awareness abilities on writing achievement.

### *Fluid Reasoning*

McGrew and Knopik (1993) found that the WJ-R Fluid Reasoning cluster demonstrated moderate effects on both basic writing skills and written expression from age 5 to approximately age 12 years. Although the WJ-R and WJ III Fluid Reasoning clusters and the Written Expression clusters are almost identical in composition, this study identified mainly negligible effects of Fluid Reasoning until late adolescence when considering both basic writing skills and written expression.<sup>6</sup>

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<sup>6</sup> The only differences between the WJ-R and WJ III Written Expression clusters stem from addition and substitution of a few items on the Writing Samples and Writing Fluency tests, and an increase in the size of the items blocks on the Writing Samples test.

Even when these effects were moderate in late adolescence, they remained at the lowest levels of this range. These differences from those of past research are most likely due to other cognitive clusters now accounting for more of the writing variance, or they may reflect a significant change in cohort experiences.

### *Visual-Spatial Thinking*

Although visual processing abilities may contribute to the earliest stages of spelling acquisition, this study indicates primarily negligible effects of Visual-Spatial Thinking on writing achievement throughout the period of analysis. These results replicate the findings from McGrew and Knopik (1993). It is likely that orthographic coding skills, which were not targeted in this study, account for the expected relations between visual processing abilities and writing skills (Berninger, 1994).

### *Limitations*

The results of this study may be limited in several ways. First, because this study relied on simultaneous multiple regression analyses in which all relevant cognitive variables were concurrently submitted as predictors, some abilities may be judged to be unimportant to writing achievement when analyzed with other abilities that account for a greater proportion of the writing variance. Second, this study used a cross-sectional design and examined the CHC cognitive abilities that predict concurrent writing achievement, but longitudinal designs are also needed. Third, several predictor and criterion variables used in this study may tap into some of the same abilities. For example, the WJ III Writing Fluency test, which is included in the Written Expression cluster, is timed, and points are awarded based on speed of production. Thus, the relative importance of the WJ III Processing Speed cluster to the prediction of Written Expression is not unexpected because the latent ability Processing Speed appears to influence both sets of scores (McGrew & Woodcock, 2001). Similarly, the two tests contributing to the Processing Speed cluster require the proficient use of a pencil, as do the four writing tests. Thus, it is possible that the resulting measures share variance attributable to shared methods of responding. Fourth, it is likely that the tests included in the Written Expression cluster measure only a narrow range of writing composition skills. Thus, other tests of written expression that require longer, more complex responses (e.g., writing 10 paragraphs based on a picture cue) may have yielded somewhat different results. Finally, the results of our analyses indicated that the combination of CHC ability measures typically accounted for approximately half of the variance in the writing variables. Thus, it is probable that inclusion of additional predictors (e.g., orthographic knowledge, knowledge of writing strategies) would provide a better explanation of writing achievement. Future research should include more comprehensive measures of written expression and include influences outside the cognitive realm as predictors of writing achievement.

### *Implications*

Although (a) CHC theory is only one of several viable theories that explain performance on cognitive and achievement tasks (see Flanagan & Harrison, 2005) and (b) other approaches to assessment may offer a more direct link to intervention (see Shapiro, 2005), the results of this study have implications for the selection and use of a constellation of WJ III cognitive clusters and other such composites based on CHC theory (see Flanagan, Ortiz, Alfonso, & Mascolo, 2006) during selective testing focused on understanding writing achievement. For example, measures of Comprehension-Knowledge, Processing Speed, Short-Term Memory, and Long-Term Retrieval abilities may help explain, at least partially, why some children with deficits in basic writing skills or written expression do not respond to interventions. Despite the logical and theoretical links between

Auditory Processing abilities and spelling accuracy, it does not appear that these abilities (at least as measured by the WJ III) are important relative contributors to explaining children's writing difficulties beginning at age 7 years. In addition, Fluid Reasoning and Visual-Spatial Thinking abilities do not seem to be important relative contributors to the explanation of such difficulties. Thus, psychologists in the schools may benefit from use of measures of the four CHC broad abilities that are most explanatory of writing achievement as part of a broader assessment.

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