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Gender Matters in Neuropsychological Assessment of Child and Adolescent Writing Skill

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Abstract

Gender differences in Cattell-Horn-Carroll cognitive explanatory variables of basic writing skills and written expression in children and adolescents in grades 1–12 were explored using multiple-group structural equation modeling with the standardization samples for the Woodcock Johnson IV ($N = 3569$). Results showed small female advantages in cognitive processing speed and written expression across grade levels. Crystallized ability, fluid reasoning, short-term working memory, processing speed, and auditory processing were significant predictors of basic writing skills with learning efficiency showing stronger effects on basic writing skills for males compared to females in grades 9–12. Additionally, fluid reasoning, short-term working memory, processing speed, learning efficiency, and visual processing were significant predictors of written expression. Processing speed had stronger effects on written expression for males compared to females in grades 9–12, whereas auditory processing had stronger effects on written expression for females compared to males in grades 9–12. Theoretical and practical implications of findings are discussed.

Keywords Writing achievement · Gender differences · Multiple group structural equation models · CHC abilities · Woodcock Johnson tests

Individual differences in cognitive abilities explain individual differences in writing achievement and are often used in explanatory models of writing (Abbott and Berninger 1993; Hayes 2006; Kim and Schatschneider 2017). A number of cognitive abilities associated with writing achievement across school-age development are well-supported in the empirical literature (Benson et al. 2016; Caemmerer et al. 2018; Cormier et al. 2016; Decker et al. 2016; Floyd et al. 2008; McGrew and Knopik 1993; Niileksela et al. 2016). As children mature and begin to more effectively utilize writing to facilitate learning, cognitive influences on writing performance change. In other words, the cognitive variables important for writing shift across grade level as a function of writing skill development, where children progress from learning how to write to using writing as a method to communicate and demonstrate knowledge in an integrative and coherent manner (Abbott and Berninger 1993; Hajovsky et al., 2018b). When the writing demands shift and intensify across school-age development, different cognitive abilities are required at different levels across developmental age (or grade) groups.

Another variable that influences writing scores is gender (Reilly et al. 2019; Scheiber et al. 2015). Females show moderate advantages in written expression, manifesting early in development and these differences persist across development (Reynolds et al. 2015). Research has shown that cognitive explanatory models of writing differ between females and males during the emergent years of writing development, which may partially explain these observed differences. For instance, female advantages in specific skills related to processing speed, executive functioning, or language skills may explain some of this advantage. However, a comprehensive examination of a wider range of cognitive constructs, how they relate to writing, and how gender may moderate those relations, has not been completed. The purpose of the current

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study is to determine whether the patterns of relations and strength of relations between cognitive variables and writing differ across grade-level groups and between genders.

Gender Differences in Writing

One potential explanation that may support a female edge in writing includes gender differences in lateralization of brain function. Research has shown that females tend to show more even distribution of brain regions responsible for language use across left and right cerebral hemispheres (e.g., Burman et al. 2008; Clements et al. 2006). This bilateral activation may result in improved processing and increased performance on language tasks, which includes writing. Alternatively, the neuropsychological processes involving executive functions may serve as a potential explanation for the observed gender difference in writing. For example, Matthews et al. (2009) examined self-regulation skills using indirect and direct measures in a sample of 268 kindergarteners. A female advantage was found on both measures, suggesting gender differences in early self-regulatory behaviors may help to explain gender differences in writing.

For example, findings suggest that fluency in retrieval of words explains more individual differences in writing for girls than for boys in grades 1–4; conversely, during the same period of time short-term working memory explains more individual differences in writing for boys than for girls (Hajovsky et al., 2018b). A significant limitation of some past findings is that other measures of cognitive abilities important for writing were not included while accounting for gender and developmental differences. For example, given that females show an advantage in processing speed relative to males (Camarata and Woodcock 2006; Keith et al. 2011) and that processing speed is also related to writing development, processing speed should be included in an explanatory model of writing especially when examining gender as a moderating variable. Similarly, auditory processing influences writing performance with differences found across ages (e.g., Cormier et al. 2016) and therefore should be included in gender-based developmental models of writing.

Theoretical and Neuropsychological Models of Writing

The link between cognitive explanatory variables and writing performance can be informed, in part, by theoretical models of writing (Berninger 1999; Graham et al. 1997). Although theories of writing tend to be underspecified regarding specific cognitive components (Kim and Schatschneider 2017), they capture some basic processes that guide our understanding of writing development. Specifically, the process of translation represents the cognitive action of encoding ideas into language representations or oral language propositions (Kim and Schatschneider 2017). Conversely, the process of transcription involves transcribing language representations into written symbols (Berninger 1999; Graham et al. 1997). Translation processes represent more language-generative skills (e.g., text and idea fluency), whereas transcription processes represent more mechanical and motor-related skills (e.g., spelling and handwriting fluency) that are necessary, but insufficient for producing complex works of writing quality. The acquisition and automatization of fine motor-related transcription skills across development allows children to use more resources for mentally complex translation skills (Berninger 1999; Berninger and Winn 2006; Graham et al. 1997; Kim and Schatschneider 2017), where underlying cognitive abilities (e.g., Hajovsky et al., 2018b) and executive functioning processes (e.g., Berninger et al. 2017) help explain individual differences in writing performance. For example, when children are learning to write (i.e., primarily transcription), cognitive variables important for storing the alphabetic code and orthographic knowledge, including visual word forms, explain writing performance differences among individuals (Mather and Wendling 2018). As children mature and basic transcription skills begin to operate with automaticity, language and vocabulary explain individual differences in written expression (i.e., translation skills; Hajovsky et al., 2018b). Thus, background knowledge variables become more important in evaluating writing, especially in more competent products of writing quality (Hajovsky et al. 2018a).

From a neuropsychological perspective, writing involves the use of expressive language skills but differs in that writing requires the production of lexical content in the form of orthographic symbols rather than spoken language. Expressive language is especially important in the translation processes of writing because a knowledge of language is required for using appropriate rules for syntax and grammar when creating written products (Berninger 1999; Kim and Schatschneider 2017). Specifically, orthographic mapping, or the ability to accurately form images of individual letters and the spelling patterns of our language in memory (Proctor et al. 2017), is especially important in writing. When writing, individuals must use orthographic retrieval to recall spelling patterns from memory or use a non-lexical phoneme-grapheme conversion procedure for spelling unfamiliar words (Rapcsak 1997). Ellis (1982, 1988) suggests that written language consists of a central/linguistic component and a peripheral motor component. The central/linguistic processes are involved in initiating the writing sequence and include the selection of correct words and spellings. During this phase, strings or patterns of graphemes are transferred to working memory within a graphemic buffer, where the graphemes are then converted into writing by the peripheral component. The writer must then select the correct form for each grapheme from their long-term memory storage. The peripheral motor component is then used in the formation of graphemes, which requires an understanding of how they are mapped in space and what motor movements (e.g., sequence and direction of movements) are required to create those graphemes (Chittooran and Tait 2005). The measurement of human cognitive abilities provides a soft mapping of some of the underlying neuropsychological processes that are important for writing, especially the linguistic and memory processes involved in writing. Below, the structure and conception of human cognitive abilities as articulated within a theoretical and validated framework are reviewed and their relations to writing are examined.

Structure of Human Cognitive Abilities

The structure of underlying individual differences in human cognitive abilities is mapped according to the Cattell-Horn-Carroll (CHC) theory (Carroll 1993; Schneider and McGrew 2018), and gives a common nomenclature to study cognitive abilities and writing development. CHC theory is a multidimensional, hierarchical working model of intelligence that posits many different cognitive abilities that exist at three layers or strata. At the vertex is general intelligence (also referred to as the *g* factor or psychometric *g*), which is the highest level of cognitive generality or abstraction (Jensen 1998). At the next level are domain-specific abilities (e.g., comprehension-knowledge) which are also referred to as broad abilities. These broad abilities are sometimes of primary interest when examining how specific cognitive abilities relate to specific areas of achievement (Hajovsky et al. 2014; Keith 1999; Niileksela et al. 2016; Villeneuve et al. 2019). Last, the lowest stratum consists of over 80 different narrow abilities (e.g., language development), which represent different skills that underlie broad abilities.

Summary of Cognitive Abilities and Writing Research

The main research findings that pertain to how cognitive abilities relate to basic writing skills and written expression are described below. A description of each cognitive ability measure employed in this study is located in Table 1. First, the *g* factor is typically one of the strongest predictors of educational achievement (Gottfredson 1997; Jensen 1998; Kaufman et al. 2012). Psychometric *g* has shown large direct (Hajovsky et al. 2018b; Niileksela et al. 2016) and indirect (Hajovsky et al. 2018b) relations with basic writing skills and written expression depending on the type of model used (i.e., bifactor vs. higher-order, see Benson et al. 2016; Hajovsky et al. 2018b). Similarly, fluid reasoning (G*f*) has shown moderate to large relations with basic writing skill and written expression (Cormier et al. 2016; McGrew and Knopik 1993), although some studies have not found this relation with written expression (Floyd et al. 2008). However, other studies found that fluid reasoning is redundant with psychometric *g* and therefore do not estimate relations between fluid reasoning and written expression (Benson et al. 2016; Hajovsky et al. 2018b).

One of the most consistent specific cognitive abilities shown to relate to multiple areas of academic achievement is comprehension-knowledge, or crystallized ability[1] (G*c*; Flanagan et al. 2013; McGrew and Wendling 2010). Comprehension-knowledge has shown moderate to large relations with basic writing skill and written expression (Cormier et al. 2016; Floyd et al. 2008; McGrew and Knopik 1993; Niileksela et al. 2016), with studies suggesting that comprehension-knowledge has a developmental relation with basic writing skills and written expression that increases with age (Cormier et al. 2016; Hajovsky et al. 2018b). However, prior research with the WJ IV co-normed standardization sample data found that comprehension-knowledge did not relate to written expression once other cognitive abilities were controlled (Cormier et al. 2016; Niileksela et al. 2016). Although comprehension-knowledge is broader than oral language (comprehension-knowledge includes both listening ability and expressive language, as well as other language-related skills like lexical knowledge and general information; see Schneider and McGrew 2018), language is a significant component of comprehension-knowledge and it is not surprising that this broad ability is related to basic writing skills and written expression.

Some cognitive constructs facilitate writing via language storage, retrieval, or overall efficiency of mental processing. Each of these underlying processes have been shown to be related to basic writing skills and written expression. For example, learning efficiency (G*l*) has shown mixed results in different versions of the Woodcock Johnson (WJ) family of batteries (Cormier et al. 2016; Floyd et al. 2008), although it was referred to as long-term storage and retrieval (G*lr*) in those studies. The subtests that comprise the long-term storage and retrieval composite have changed since the WJ IV Tests of Cognitive Abilities (Schrank et al. 2014a) was released. On the WJ III, the relations of long-term storage and retrieval on both basic writing skills and written expression may be due to the inclusion of retrieval fluency, which is no longer a part of that composite on the WJ IV (Cormier et al. 2016). One study showed that learning efficiency had developmental relations with written expression that decreased over time (Hajovsky et al. 2018b). Niileksela et al. (2016) could not test the learning efficiency and written expression relation as learning

[1] Researchers disagree on whether G*c* represents more of an underlying cause of individual differences (biological capacity) or whether it is simply a statistical entity (Kan et al. 2011).

Table 1 Woodcock Johnson Cognitive and Achievement Composite Score Median Reliabilities and Descriptions

Measure	Median reliability	Description
WJ IV cognitive composite		
Comprehension-knowledge (G*c*)	.93	Depth and breadth of declarative and procedural knowledge and skills valued by one's culture. Comprehension of language, words, and general knowledge through experience, learning, and acculturation
Cognitive processing speed (G*s*)	.94	The ability to control attention to automatically and fluently perform relatively simple repetitive cognitive tasks
Auditory processing (G*a*)	.92	Ability to perceive, discriminate, and manipulate sound information, includes processing auditory information in primary memory and activation, restructuring, or retrieval of information from semantic-lexical memory
Short-term working memory (G*wm*)	.91	The ability to encode, maintain, and/or manipulate auditory or visual information in primary memory to solve multiple-step problems
Learning efficiency (G*l*)	.97	The ability and efficiency to learn, store, and consolidate new information in long-term memory stores
Fluid reasoning (G*f*)	.94	Deliberate and controlled focused attention to solve novel problems that cannot be solved using prior knowledge. Reasoning that depends minimally on learning and acculturation
Visual processing (G*v*)	.86	The ability to use mental imagery, store images in primary memory, or perform visual-spatial analysis or mental transformation of images
WJ IV achievement composite		
Basic writing skills	.95	The ability to spell words according to specific orthographic rules and knowledge of the mechanics of writing (e.g., spelling, capitalization, punctuation)
Written expression	.92	The ability to use text to communicate ideas clearly and copy or generate text quickly

Note. WJ IV Cognitive and WJ IV Achievement composite descriptions adapted from Schneider and McGrew (2018). WJ IV = Woodcock Johnson Tests, Fourth Edition

efficiency (i.e., long-term storage and retrieval in Niileksela et al. 2016) and psychometric *g* were found to be indistinguishable, although psychometric *g* had a direct relation with a written expression subtest, Writing Samples. While learning efficiency (G*l*) primarily involves storage and consolidation of learned material, the construct of retrieval fluency (G*r*) involves the retrieval rate and fluency of learned material. Within CHC theory, these two abilities have been conceptualized as more independent and may be best considered separately (Jewsbury and Bowden 2017; Schneider and McGrew 2018). The construct retrieval fluency has shown differential relations with written expression, where females demonstrated large relations and males demonstrated moderate relations at grades 1–4 (Hajovsky et al. 2018b). Processing speed (G*s*) has shown moderate to large relations with basic writing skills and written expression across development (Cormier et al. 2016; Niileksela et al. 2016) with decreases found over time (Cormier et al. 2016; Floyd et al. 2008; McGrew and Knopik 1993). Processing speed may facilitate writing via an increase in automatization and reduction in cognitive load, therefore freeing resources for more complex writing tasks (Cormier et al. 2016; Floyd et al. 2008), which may be why processing speed tends to explain individual differences in younger writers compared to older writers. Further, females have demonstrated an advantage in latent processing speed (Camarata and Woodcock 2006), which may extend to a differential processing speed and written expression relation between males and females. It is important to note that the types of writing tasks used in the current study are structured writing tasks that focus on spelling words, providing one-word answers to prompts, and writing short sentences. These types of writing tasks are less similar to the more complex unstructured writing tasks that are commonly seen in middle and high school. This may partially explain why processing speed is generally found to have a stronger influence on writing for younger children in the empirical literature, as these structured writing tasks approximate the writing curriculum of younger students, but not older students. Nonetheless, it is plausible that faster processing speed allows for more efficient use of other neuropsychological processes (e.g., verbal short-term memory, verbal fluency) working together to generate more complex and coherent writing in older writers.

Another integral cognitive ability important for basic writing skills and written expression is short-term memory (G*sm*)/short-term working memory (G*wm*). Writing is complex and involves the balance and coordination of multiple mental processes for checking and monitoring one's writing (Kim and Schatschneider 2017). Research supports the relation between short-term memory/short-term working memory and in both basic writing skills and written expression (Cormier et al. 2016; Floyd et al. 2008). The influence of short-term working memory on basic writing skills tends to be moderate, and the effect increases across development (Cormier et al. 2016; Floyd et al. 2008). Short-term memory and written expression relations have also shown differentiation between males and females with males showing a moderate relation with written expression in grades 1–4, but females showing no relation (Hajovsky et al. 2018b).

Due to different subtests comprising the auditory processing (G*a*) composite across the iterations of the WJ batteries, there have been inconsistent findings with writing achievement variables (cf. Cormier et al. 2016; Floyd et al. 2008; McGrew and Knopik 1993). Auditory processing has shown moderate effects on basic writing skills primarily in the elementary ages with the WJ-R (McGrew and Knopik 1993), but this composite included two phonological processing subtests. It is hypothesized that auditory processing assists with initial sentence formation for younger writers and in revision of writing for older writers (Cormier et al. 2016; Floyd et al. 2008; McGrew and Knopik 1993). In research with the WJ IV, auditory processing did not show a relation to written expression (Niileksela et al. 2016). One potential reason for the differences between studies may be due to the inclusion of a speed of lexical access (LA) construct (a narrow ability of retrieval fluency) in the Niileksela et al. study, which showed a weak relation with written expression at ages 6–13. The speed of lexical access and written expression relation may account for the lack of auditory processing. For example, as speed of lexical access involves the retrieval of learned information, it may account for any variability that was associated between auditory processing and written expression.

Last, visual processing (G*v*) has shown moderate to large relations with written expression (Hajovsky et al. 2018b; Niileksela et al. 2016), although some prior research has shown no relation (Cormier et al. 2016; Decker et al. 2016; Floyd et al. 2008; McGrew and Knopik 1993). Visual processing has not shown a relation with basic writing skills (Cormier et al. 2016; Floyd et al. 2008; McGrew and Knopik 1993); however, it has been noted that orthographic coding is likely implicated in the acquisition of spelling (Floyd et al. 2008). Although differences between studies are difficult to reconcile, writing necessarily involves visual-motor planning and orthographic processing skills and these are just not likely measured well on many of the cognitive tests used in previous research.

Rationale and Purpose of Current Study

Although the pattern and strength of relations between cognitive abilities and writing achievement may be assumed to generalize across school-age development and gender, prior research suggests this is not the case (Abbott and Berninger 1993; Hajovsky et al. 2018b). If cognitive explanatory models of writing do not generalize across grade levels or gender, then an overarching cognitive explanatory model of writing development may not generalize across selected populations (Widaman et al. 2013). Evidence from previous research in neuropsychology and cognitive-writing relations suggest that there may be some important differences between males and females in which cognitive and neuropsychological variables influence writing.

In the current study, we use multiple group structural equation modeling (MG-SEM) with a large, nationally representative sample to assess whether cognitive ability and writing achievement (i.e., basic writing and written expression) relations differ across grade levels or gender using a fuller set of relevant cognitive constructs than has been used in previous research (e.g., Hajovsky et al. 2018b).

Research Questions

1. Previous research has found gender differences in processing speed, basic writing skills, and written expression. Are there mean gender differences on the WJ IV COG composites and on the WJ IV ACH Basic Writing Skills and Written Expression composites in children and adolescents (grades 1–12)?
2. With the previous research on gender differences across cognitive and writing constructs, it may be possible that there are differences in how these constructs are related to each other. Does gender moderate the influence of CHC-based cognitive abilities (i.e., G*c*, G*s*, G*a*, G*wm*, G*l*, G*f*, and G*v*) on Basic Writing Skills and Written Expression?
3. Finally, there are also developmental differences in how cognitive constructs influence writing, and it is possible that there is an interaction between gender and development in how cognitive constructs influence writing. If gender moderates the influence of CHC-based cognitive abilities on Basic Writing Skills and Written Expression, are these relations different at different developmental grade levels (i.e., grades 1–4, 5–8, and 9–12) across genders?

Method

Participants

The co-normed standardization samples for the Woodcock Johnson IV Tests of Cognitive Abilities (WJ IV COG; Schrank et al. 2014a) and the Woodcock Johnson IV Tests of Academic Achievement (WJ IV ACH; Schrank et al. 2014b) were used to examine the relations between CHC-based cognitive abilities and writing achievement in school-age children. The complete norming sample ($N = 7416$)

represented 100 geographically diverse communities and was obtained using a stratified random sampling method designed to be representative of the US population across 46 states and the District of Columbia (McGrew et al. 2014). The demographic features matched those of the general US population according to the 2010 Census (McGrew et al. 2014). More information concerning specific demographic characteristics is located in the WJ IV *Technical Manual* (McGrew et al. 2014). The sample used for this study is the school-age subsample that included grades 1–12, inclusively ($N = 3569$). The sample was divided into three groups by grade level: grades 1–4 ($n = 1281$); grades 5–8 ($n = 1267$); and grades 9–12 ($n = 1021$). The disaggregation of grade groups was selected to approximate the critical grade transition from fourth to fifth grades where important executive functioning changes occur for writing development (Altemeier et al. 2008) and where children are transitioning from learning to write to using writing as a method for demonstrating and facilitating learning. Further, the grade splits represent those used in prior research (see Hajovsky et al. 2018b).

Measurement Instruments

WJ IV

The WJ IV COG is an individually administered intelligence test for individuals ages 2–90+ years. Its development was guided by contemporary CHC research and theory (Carroll 1993; McGrew et al. 2014; Schneider and McGrew 2018). The WJ IV COG consists of a standard battery, which includes ten tests, and an extended battery consisting of an additional eight tests. Composite scores for the cognitive abilities including Comprehension-Knowledge (G*c*), Cognitive Processing Speed (G*s*), Auditory Processing (G*a*), Working Memory (G*wm*), Long-Term Retrieval (G*lr*), Fluid Reasoning (G*f*), and Visual Processing (G*v*) were used for all analyses. The CHC cluster scores (i.e., G*c*, G*s*, G*a*, G*wm*, G*lr*, G*f*, and G*v*), which form composites to represent measures of different cognitive constructs, are formed from a combination of two tests. We use the term G*l* (Learning Efficiency) to represent the construct measured by the G*lr* cluster and to reflect refinements in CHC theory (Jewsbury and Bowden 2017; Schneider and McGrew 2018). It is important to point out that although the WJ IV is branded as a cognitive abilities test, the tests are important measures of neuropsychological processes that are relevant to neuropsychological evaluations. With the most current revision of the WJ IV, psychometric considerations were made along with findings from other clinical and neuropsychological research to inform the development of the tests (McGrew et al. 2014).

Age-referenced standardized scores for the seven WJ IV COG composite scores were used as predictors in the SEM path models. The internal consistency reliability coefficients for individual tests range from .74–.97 (average = .88). The median test-retest reliability coefficients for timed tests are .88–.91 for ages 7–17 years (McGrew et al. 2014). See Table 1 for median reliability coefficients. The WJ IV Technical Manual provides extensive concurrent, criterion, and developmental validity evidence that includes an investigation of the patterns of intercorrelations among tests and clusters and a three-stage structural validity analysis using factor analysis, cluster analysis, and multidimensional scaling (see McGrew et al. 2014).

WJ IV A

The WJ IV ACH is an individually administered achievement test for individuals ages 2–90+ years (Schrank et al. 2014b). The WJ IV ACH assess multiple academic areas (i.e., Reading, Writing, Mathematics, and Academic Knowledge) in addition to multiple cross-domain clusters (e.g., Academic Fluency, Academic Skills). The WJ IV ACH consists of a standard battery, which includes 11 tests that provide information for several broad and narrow academic areas. It also includes an extended battery consisting of an additional nine tests to provide more in-depth diagnostic information for specific academic skills. The standard battery has three parallel forms, which were combined for the current study.

The WJ IV ACH Basic Writing Skills (BWS) and Written Expression (WE) composites were used as outcome variables in the current study. The BWS composite includes two subtests, Spelling and Editing. These subtests measure the examinee's ability to spell words that are heard aurally and their ability to identify errors in spelling and punctuation in short passages they read. The WE composite measures the examinee's ability to formulate words and sentences with appropriate content for specific writing tasks and the ability to quickly formulate and write short sentences about pictures. See Table 1 for median reliability coefficients.

Analysis Plan

There were three primary steps in the analysis plan. Prior to analysis, the continuous predictor variables were mean-centered to provide a clearer interpretation of findings (Keith 2019). Because we employed path models, we were able to simultaneously estimate the net effects of cognitive abilities and gender on both outcome variables.

For the first research question, descriptive standardized mean gender differences were calculated on the WJ IV COG composites and on the WJ IV ACH BWS and WE composites for each grade level group (grades 1–4, 5–8, and 9–12). The gender differences were interpreted according to Hyde's (2005) subjective effect size criteria: close-to-zero ($d \leq 0.10$), small ($0.11 < d < 0.35$), moderate ($0.36 < d < 0.65$), large ($0.66 < d < 1.00$), or very large (> 1.00).

To answer the second question, path models were used to investigate gender differences in the associations between cognitive abilities and writing achievement, or whether gender moderates the influence of cognitive abilities on writing separately for each grade level group. Path models were employed to allow the simultaneous estimation of all the predictor variables on both outcome variables rather than performing a series of separate moderated multiple regressions. BWS and WE were included as criterion variables (i.e., dependent variables) and the seven continuous cognitive ability variables (i.e., G*c*, G*s*, G*a*, G*wm*, G*l*, G*f*, and G*v*) as well as the dichotomous gender variable were included as predictor variables (i.e., independent variables). To test whether gender moderates the influence of cognitive variables on writing, the statistically significant ($p < .05$) cognitive ability main effects were multiplied by the gender variable to create cognitive ability-by-gender cross-product terms. These cross-product terms were only included in the path models when corresponding main effects were statistically significant from the first part of the analysis. The cross-product term can be interpreted as a moderator effect, where the unstandardized regression coefficient represents the gender difference in cognitive ability-writing achievement slopes.

Finally, the relations between cognitive abilities and BWS and WE were investigated for moderation between gender and across grade-level groups (grades 1–4, 5–8, and 9–12). In this step, a multiple group path model was used to test if there were differences across grade level in the pattern and/or magnitude of the influences of cognitive abilities and gender differences in writing. All statistically significant main effects and cross-product terms from the previous step were included in a single model where paths within each grade level group were estimated freely. Then, cross-group equality constraints were added to the models and the likelihood ratio test was used to determine if the magnitude of the paths differed across groups. The final path models only included statistically significant main effects (i.e., simple effects) and interaction effects with the interaction effects interpreted as conditional effects (Scheiber et al. 2015). Standardized effect sizes of statistically significant main effects were interpreted according to the following criteria: > .05, small; > .10, moderate; and > .25, large (Keith 2019).

To demonstrate the model used in the study, the path model for main effects only is shown in Fig. 1. The two outcome variables, BWS and WE, are depicted on the right side of the figure. Residual variances between BWS and WE were allowed to freely covary given the achievement composites likely share variance beyond that explained by the cognitive ability and gender predictors. Depicted on the left side of Fig. 1 are the gender and mean-centered cognitive ability predictors. The predictors were all interrcorrelated (controlled) to account for shared variance, so that only unique effects were estimated.

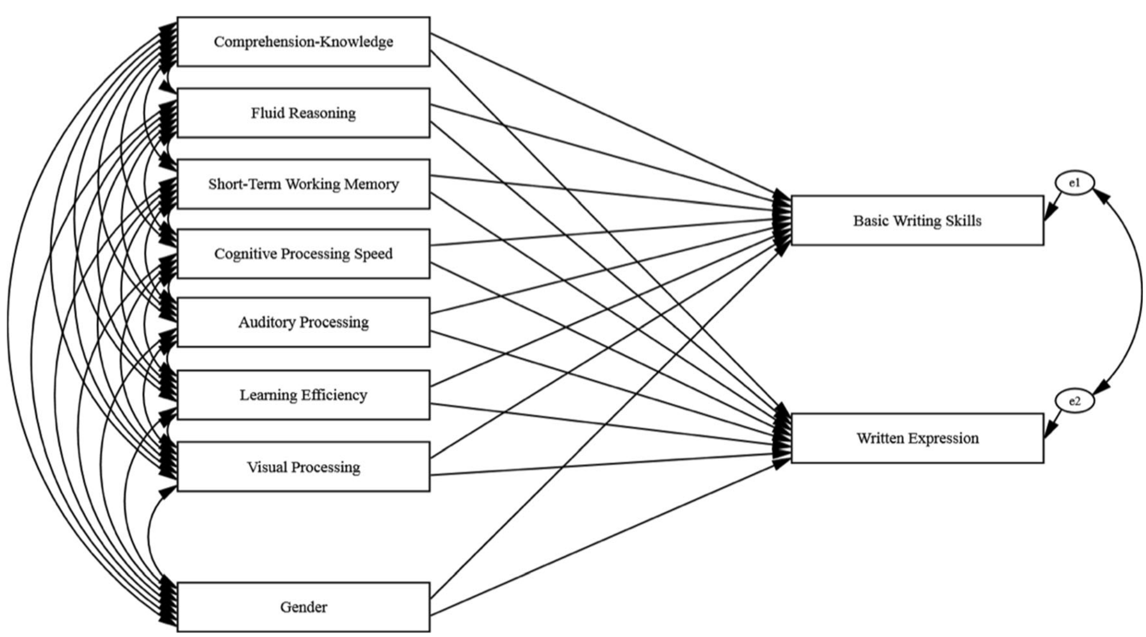

Fig. 1 Initial SEM path model with continuous and dichotomous predictors of basic writing skills and written expression. Note. All predictor variables are intercorrelated so unique effects are estimated. A freely estimated residual correlation was allowed between dependent variables to account for common shared variance not accounted for by predictor variables

Model Evaluation

All analyses were conducted in Amos (Version 25.0, Arbuckle 2017). Maximum likelihood estimation (MLE) was used to estimate all SEM path models. The root mean square error of approximation (RMSEA) and the comparative fit index (CFI) were used to assess global model fit. Acceptable criteria for model fit were: RMSEA ≤ .06 and CFI ≥ .95 (Hu and Bentler 1999; Schermelleh-Engel et al. 2003). Nested model comparisons were evaluated using the likelihood ratio test ($\Delta\chi^2$) with changes considered statistically significant at an alpha level of $p < .05$. The Akaike Information Criterion (AIC) was also reported, with lower values indicating better overall model fit (Keith 2019).

Results

Descriptive Statistics

Means, standard deviations, and standardized mean differences in observed WJ IV COG and WJ IV ACH composite scores for genders at each grade level group are reported in Table 2. The data used in the multiple group path models were composite scores from the norming samples and composite score means combined between gender for the WJ IV COG and WJ IV ACH ($M = 100$, $SD = 15$) were close to the population values across each of the grade-level groups. The normality assumptions of the composite data were also examined for viability for using MLE. Absolute univariate skewness values that approximate or exceed two and absolute univariate kurtosis values that approximate or exceed seven may yield biased results due to non-normality (Curran et al. 1996). All of the univariate distributional assumptions were within acceptable limits across grade levels (skewness = − 0.17–0.10; kurtosis = − 0.22–1.02). Minimal data were missing (< 5%). Regardless, missing data were handled with MLE so that all cases (incomplete or complete) were analyzed (Baraldi and Enders 2010).

Mean Differences Between Genders

The mean differences in the observed CHC broad ability and writing achievement composite scores provide estimates of mean differences in those constructs. The most consistent pattern of statistically significant mean differences across grade levels was a female advantage in the Processing Speed and Written Expression composites. These advantages, according to Hyde (2005), would be classified as small effect sizes. The only other statistically significant mean differences were found in the Visual Processing and Basic Writing Skills composites at grades 5–8, with females demonstrating a small advantage.

Path Models

First, the initial main effects model, G*c*, G*f*, G*wm*, G*s*, G*a*, G*l*, and Gender had statistically significant effects on BWS in at

Table 2 Descriptive statistics and Cohen's *d* effect size calculations for gender differences in composite scores for each grade level group

Composite	Grades 1–4			Grades 5–8			Grades 9–12		
	Females	Males	*d*	Females	Males	*d*	Females	Males	*d*
Comprehension-knowledge	99.56 (14.96)	99.68 (15.59)	0.06	99.82 (15.66)	100.32 (15.56)	0.03	99.93 (16.44)	101.57 (15.78)	0.10
Cognitive processing speed	101.24 (14.20)	98.95 (16.10)	**0.15+**	101.40 (15.00)	97.63 (15.61)	**0.25+**	101.25 (15.12)	97.93 (16.42)	**0.21+**
Auditory processing	100.47 (15.79)	98.92 (15.84)	0.10+	99.57 (15.48)	99.09 (16.09)	0.03+	100.97 (15.87)	100.74 (15.62)	0.01+
Short-term working memory	101.14 (15.21)	100.50 (15.16)	0.04+	100.73 (14.67)	99.75 (15.55)	0.06+	100.82 (15.58)	100.89 (16.52)	< 0.01
Learning efficiency	99.91 (15.33)	99.85 (15.97)	< 0.01+	99.94 (15.73)	99.61 (15.34)	0.02+	101.28 (15.34)	100.68 (16.25)	0.04+
Fluid reasoning	100.00 (15.16)	100.07 (15.86)	< 0.01	99.12 (14.70)	99.41 (16.08)	0.02	99.10 (15.85)	100.38 (16.21)	0.08
Visual processing	101.40 (15.42)	100.62 (16.25)	0.05+	100.90 (15.49)	98.89 (16.14)	**0.13+**	101.66 (16.28)	100.42 (15.15)	0.08+
Basic writing skills	101.45 (14.23)	99.91 (15.15)	0.10+	100.32 (15.34)	98.09 (15.73)	**0.14+**	99.75 (16.42)	100.61 (17.27)	0.05
Written expression	101.91 (16.18)	99.50 (16.25)	**0.15+**	101.23 (15.82)	98.55 (16.61)	**0.17+**	101.12 (16.93)	99.18 (16.90)	**0.11+**

Note. Mean scores are outside parentheses and standard deviations are inside parentheses. Composite scores have a mean of 100 and a standard deviation of 15. *d* = Cohen's *d* effect size. A+ indicates a female advantage. Bolded effect sizes indicate standardized mean differences are statistically significant at $p < 0.05$

Table 3 Model Fit statistics for multiple group SEM path models

	χ^2 (df)	$\Delta\chi^2(\Delta df)$	*p*	RMSEA	CFI	AIC	Decision
Moderation models							Tenable?
1. Initial model (all paths)	10.544 (12)	–	–	.000 [.000–.015]	1.000	1006.544	–
2. Paths trimmed	13.623 (18)	3.079 (6)	.799	.000 [.000–.011]	1.000	691.623	Yes
3. All paths constrained	66.830 (52)	53.207 (34)	.019	.009 [.000–.015]	1.000	676.830	No
4. Final interactions model (Model 2)	13.623 (18)	–	–	.000 [.000–.011]	1.000	691.623	–

Note*:* The $\Delta\chi^2$ is statistically significant at $p < .05$

least one grade group, whereas G*f*, G*wm*, G*s*, G*a*, G*l*, G*v*, and Gender had statistically significant effects on WE in at least one grade group. Two nonsignificant paths were removed (i.e., G*v* on BWS and G*c* on WE). The removal of these paths did not lead to a statistically significant degradation in model fit ($\Delta\chi^2$ [6] = 4.219, $p = .647$). Once all main effects were identified and retained, corresponding Gender-by-Ability interaction terms were added.

Model tests are shown for all interaction models in Table 3. In the initial interaction model (Model 1), the gender by G*c*, G*wm*, G*s*, and G*a* interaction terms did not have statistically significant effects on BWS, and the gender interaction terms of G*f*, G*wm*, G*l*, and G*v* did not have statistically significant effects on WE. The deletion of these nonsignificant interaction effects did not lead to a statistically significant degradation in model fit (Model 2: $\Delta\chi^2$ [8] = 3.079, $p = .929$). The model with all paths constrained across gender (also with interaction terms; Model 3) led to a statistically significant degradation in model fit ($\Delta\chi^2$ [34] = 53.207, $p < .05$) compared to Model 2. Therefore, the final model (Model 2) was retained. The final model with simple effects and interaction terms is shown in Fig. 2.

Basic Writing Skills

The combined effects in the final interactions model explained 58% of the total variance in BWS scores in grades 1–4 followed by 55% and 61% in grades 5–8 and 9–12, respectively. Gender had a small effect ($\beta = .04–.05$) on BWS only in grades 1–8 that favored females. The simple effects of G*c*, G*wm*, G*s*, and G*a* on BWS were statistically significant across all grades. G*c* had a large effect across all grades ($\beta = .28–.33$) on BWS, as did G*wm* ($\beta = .26–.27$). Moderate effect sizes were observed across all grades for G*s* ($\beta = .12–.13$) and G*a* ($\beta = .14–.20$). The simple effect of G*f* was only statistically significant in grades 1–8 and moderate in size ($\beta = .17–.12$). The Gender-by-G*f* interaction effect was not statistically significant across all grades. The simple effect of G*l* was also not statistically significant across all grades, but the Gender-by-G*l* interaction effect was statistically significant in grades 9–12 with stronger effects for males. Table 4 displays the standardized and unstandardized coefficients of the final interaction model for BWS.

Written Expression

In the final interactions model, the combined effects explained 46% of the total variance in grades 1–4 followed by 40% and 45% in grades 5–8 and 9–12, respectively. The simple effect of Gender was statistically significant at grades 1–8 ($\beta = .05$) but not statistically significant at grades 9–12. The simple effect of G*f* was large and statistically significant across all grades ($\beta = .27–.34$) and decreased in size (but still large) across grade levels. G*s* also showed large statistically significant effects across all grades ($\beta = .20–.41$) but increased in importance as grade level increased. G*l* also showed an increasing trend in statistically significant effects (small to moderate) from grades 1–8 ($\beta = .07$) to grades 9–12 ($\beta = .12$). The simple effect of G*v* on WE was statistically significant and small at grades 1–4 ($\beta = .06$) and grades 9–12 ($\beta = .07$), but was not statistically significant at grades 5–8. The simple effects of G*a* across all grades were not statistically significant; however, the Gender-by-G*a* effect at grades 9–12 ($\beta = .16$) was stronger for females. Conversely, the Gender-by-G*s* effect was also statistically significant at grades 9–12 ($\beta = -.18$) but stronger for males. The Gender-by-G*s* and Gender-by-G*a* effects at grades 1–8 were not statistically significant. Table 4 displays the standardized and unstandardized coefficients of the final interaction model for WE.

Discussion

The primary purpose of the current study was to examine gender differences in Cattell-Horn-Carroll–based cognitive ability influences on basic writing skills and written expression across grade levels (i.e., grades 1–4, 5–8, and 9–12). A secondary purpose was to examine gender differences in the cognitive and writing achievement composites at different grade levels. We focused on composite scores, which are designed to measure Cattell-Horn-Carroll cognitive and achievement constructs, as these scores are what practitioners typically employ.

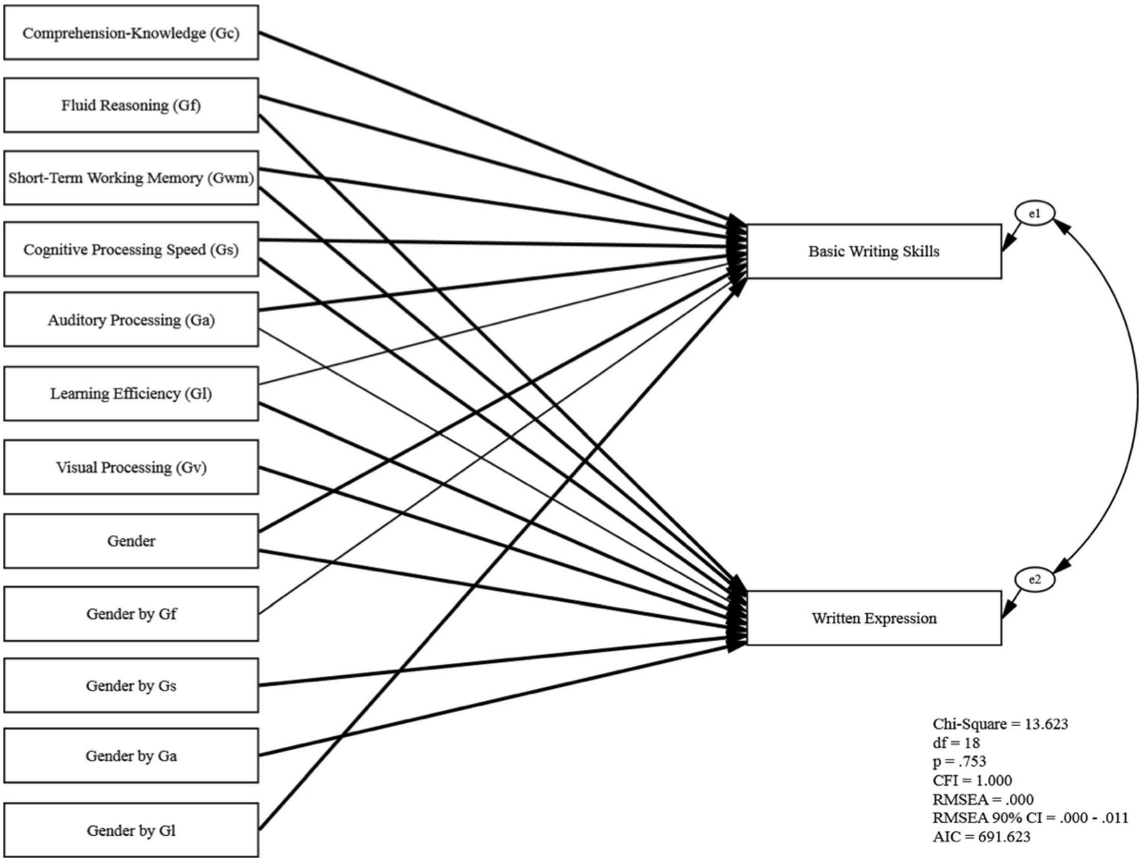

Fig. 2 Final SEM path model with continuous and dichotomous predictors of basic writing skills and written expression. Note. All predictor variables are intercorrelated (correlations not shown) so unique effects are estimated. A freely estimated residual correlation was allowed between dependent variables to account for common shared variance not accounted for by predictor variables. Bolded paths indicate statistically significant effects for at least one grade group

Gender Differences in Means

Gender differences were observed in Cattell-Horn-Carroll broad ability composite scores. The most consistent pattern of mean differences across grades was a small female advantage in cognitive processing speed ($d = 0.15–0.25$) and written expression ($d = 0.11–0.17$). There were less consistent findings of a small female advantage in basic writing skills ($d = 0.14$) and visual processing ($d = 0.13$) at grades 5–8. Findings of any male advantages (e.g., comprehension-knowledge) were negligible and statistically nonsignificant.

The findings of a consistent female advantage in processing speed and written expression overlap with findings from previous research. For example, Camarata and Woodcock (2006) found evidence of a female advantage in processing speed in elementary, middle, and high school cohorts in three different WJ standardization samples (i.e., WJ-77, WJ-R, and WJ III; Woodcock and Johnson 1977; Woodcock and Johnson 1989; Woodcock et al. 2001) and in meta-analyses combining different cognitive measures (Roivainen 2011). We extend those findings by showing evidence of a consistent female advantage in processing speed within the WJ IV standardization sample although not as large as in previous research. In addition, a female advantage in writing achievement has been found in prior versions of the WJ with a small average effect size ($d = 0.33$) reported across ages 5 to 79 years (Camarata and Woodcock 2006). Similarly, Hajovsky et al. (2018b) found a moderate female advantage in written expression ($d = 0.41–0.48$) using the Kaufman Test of Educational Achievement, Second Edition (KTEA-II; Kaufman and Kaufman 2004a) standardization sample. These findings overlap with data from the National Assessment of Educational Progress (NAEP), in which moderate-sized gender differences on writing were observed in very large samples at grade 4 ($d = 0.42$), grade 8 ($d = 0.62$), and grade 12 ($d = 0.55$) (Reilly et al. 2019). In the current study, the female advantage in basic writing skills was only observed at grades 5–8, not in other grades. One component of basic writing skills, spelling, has been found to favor females

Table 4 Standardized and unstandardized cognitive ability influences on basic writing skills and written expression in final interactions model

Regression path	Grades 1–4	Grades 5–8	Grades 9–12
BWS direct effects			
Gc	**.28 (.27)**	**.30 (.30)**	**.33 (.34)**
Gf	**.17 (.16)**	**.12 (.12)**	.04 (.04)
Gwm	**.26 (.25)**	**.27 (.28)**	**.26 (.27)**
Gs	**.13 (.13)**	**.21 (.12)**	**.12 (.13)**
Ga	**.14 (.13)**	**.20 (.19)**	**.20 (.21)**
Gl	.02 (.01)	−.09 (−.09)	.09 (.10)
Gender	**.04 (1.11)**	**.05 (1.61)**	− .01 (− .47)
Gender-by-Gf	.08 (.05)	.06 (.04)	.12 (.08)
Gender-by-Gl	− .09 (− .06)	− .03 (− .02)	**− .21 (− .14)**
WE direct effects			
Gf	**.34 (.36)**	**.32 (.33)**	**.27 (.29)**
Gwm	**.10 (.10)**	**.11 (.11)**	**.11 (.11)**
Gs	**.20 (21)**	**.27 (.29)**	**.41 (.44)**
Ga	.07 (.08)	− .02 (− .02)	− .08 (− .08)
Gl	**.07 (.08)**	**.07 (.08)**	**.12 (.12)**
Gv	**.06 (.06)**	.03 (.03)	**.07 (.08)**
Gender	**.05 (1.68)**	**.05 (1.62)**	.04 (1.27)
Gender-by-Gs	.00 (.00)	− .05 (− .03)	**− .18 (− .13)**
Gender-by-Ga	.05 (.03)	.10 (.07)	**.18 (.12)**

Note: Unstandardized coefficients are shown in parentheses. All direct effects in bold were statistically significant at $p < .05$. Negative effect sizes for Gender and Gender interaction variables favor males. G*c* = Comprehension-Knowledge; G*f* = Fluid Reasoning; G*wm* = Short-Term Working Memory; G*s* = Processing Speed; G*a* = Auditory Processing; G*l* = Learning Efficiency; G*v* = Visual Processing

(Hyde 2005; Reynolds et al. 2015), which likely translates to better developed transcriptional processes (Hajovsky et al. 2018a) and possibly early writing advantages for females (Hajovsky et al. 2018b). The least consistent finding with previous research regarding mean differences was the small female advantage ($d = 0.13$) in visual processing at grades 5–8. Other researches with the WJ III have found no gender differences in visual processing, whereas a male advantage was found in the Kaufman Assessment Battery for Children, Second Edition (KABC-II; Kaufman and Kaufman 2004b) standardization sample (Hajovsky et al. 2018b) and the Differential Ability Scales, Second Edition (DAS-II; Elliott 2007) standardization sample (Keith et al. 2011). It is possible this difference is simply due to sampling error, especially considering that the effect size was not very large overall.

Cognitive Explanatory Variables of Writing Across Grades and Between Genders

As our main goal of the study, we found that CHC-based cognitive variables operated on both basic writing skills and written expression and showed some differences between genders and across grade levels. Models with gender and interaction terms are the interpretive focus and are discussed in the context of past research. Although there is overlap between studies, findings on the relations between cognitive abilities and writing are complicated by differences in task measurement and analytic choices. For example, many studies have used different test batteries, which include different measures of writing achievement. Measures of writing may differ in their task requirements (e.g., contrived writing vs. spontaneous writing), test administration characteristics (e.g., timed vs. untimed, group vs. individual), or in the scoring structure (e.g., content, grammar, mechanics) used to evaluate the quality of writing. Further complications arise in the cognitive ability and writing relations literature due to the disaggregation of groups (e.g., ages/grades) and the different configurations of cognitive abilities included in studies, all of which likely contribute to different findings across the literature.

Basic Writing Skills

Findings from the current study overlap with previous results examining cognitive and writing achievement relations, especially with research using the WJ IV standardization sample (Cormier et al. 2016). At the same time, this study offers new knowledge by examining how gender interacts with cognitive ability influences on basic writing skills and written expression in school-age children. Specifically, we found that comprehension-knowledge was the strongest predictor of basic writing skills with large effects observed across grades 1–12. In addition, auditory processing and short-term working memory had consistent moderate-to-large effects at all grades. Fluid reasoning had moderate effects in grades 1–8, but was statistically nonsignificant at grades 9–12. This finding overlaps in part with Cormier et al. (2016) who found that fluid reasoning was more important at younger ages, but not in older ages. Learning efficiency (referred to as G*lr* in the Cormier et al. 2016 study) and visual processing did not have statistically significant effects on basic writing skills once they were controlled in the final model with interaction terms. Finally, the effect of learning efficiency on basic writing skills was moderated by gender, where learning efficiency had stronger effects on basic writing skills in grades 9–12 for males as compared to that of females. In other words, learning efficiency explained relatively more individual differences in basic writing skills for males than females.

Written Expression

The results of cognitive ability influences on written expression also overlapped with previous research but diverged in some specific and important ways. First, we found that fluid reasoning had large effects on written expression across all grades, consistent with Cormier et al. (2016) across ages 6–19. Similar to past research, processing speed had moderate-to-large effects in grades 1–12. Some small differences emerged between the current study and previous research. We found that short-term working memory had small-to-moderate effects on written expression, whereas Cormier et al. (2016) found short-term working memory had similar effects on written expression but was stronger around age 17. Similarly, in the current study, auditory processing did not have statistically significant effects on written expression, whereas Cormier et al. (2016) found that auditory processing had a moderate effect up until age 10, but then the effects of auditory processing on written expression became negligible. Additionally, we found that learning efficiency had consistent small-to-moderate effects on written expression across grades, whereas visual processing had inconsistent small effects across grades. Finally, we found two moderator effects across gender at grades 9–12. Specifically, at these grade levels, processing speed had stronger effects on written expression for males whereas auditory processing had stronger effects on written expression for females. In this manner, processing speed explained relatively more individual differences in written expression for males compared to females whereas auditory processing explained relatively more individual differences in written expression for females compared to males.

While the current study extends prior research by examining gender moderation in important explanatory variables of writing, there was a significant overlap with prior research. Nonetheless, differences with previous research were observed and we argue that some of these differences emerged due to the inclusion of gender and gender by ability interaction terms within the models in the current study. Moreover, while the subjective effect size criteria used to gage the magnitude of main effects between studies differed, the effects themselves were similar.[2]

Implications

The findings from the current study show that cognitive abilities have differential effects on basic writing skills and written expression, and these relations change as writing skills develop when the writing demands change across grade levels. In support, comprehension-knowledge had consistent albeit slightly larger effects on basic writing skills with increases in grade level. Developmentally, as children age, their vocabulary increases which, in turn, affects their skill level with spelling and composing text (Kim and Schatschneider 2017). Conversely, fluid reasoning effects on basic writing skills decreased with grade level. As the rules and mechanics of writing become mastered, the depth of prior learning naturally increases as these skills are stored as background knowledge (comprehension-knowledge) over time (Hajovsky et al. 2018b). Short-term working memory had large effects on basic writing skills across grade levels, consistent with prior research (Cormier et al. 2016; Floyd et al. 2008). Short-term working memory almost certainly facilitates compositional fluency captured within basic writing skills (Swanson and Berninger 1996). Similarly, processing speed had consistent effects on basic writing skills, which facilitates the development of automaticity in subskills necessary for writing. Last, auditory processing had consistent effects that slightly increased over time. Auditory processing may assist with understanding how words are decoded and encoded, an essential skill necessary for spelling words during sentence formation.

The findings from this study are consistent with the model of writing from Ellis (1982, 1988), where the central/linguistic processes (i.e., comprehension-knowledge in the current study) were related to basic writing skills at all grade levels and is posited to be related to initiating writing sequences through the selection of words and spellings. These must be transferred to working memory (i.e., short-term working memory in the current study) in order to be produced into writing, and short-term working memory was significantly related to basic writing skills and written expression in the current study. Although the WJ IV does not specifically measure motor skills or handwriting that would be relevant for the peripheral/motor component of Ellis's model, this study does provide some evidence regarding the importance of the central/linguistic processes in relation to writing skills.

As writing has been defined as occurring within an ill-defined problem space (Troia et al. 2017), it was hypothesized that cognitive abilities would have differential influences on basic writing skills compared to written expression compared across grade levels. For example, fluid reasoning had large effects on written expression and it is likely necessary for navigating that ill-defined problem space of writing, one that has no definite solution for the individual engaged in writing. Instead, the writer must plan, organize, and revise throughout the process of writing, requiring fluid reasoning abilities which have also shown measurement overlap with executive functioning (i.e., a broad executive function factor influenced performance on the WJ III Concept Formation test; Floyd et al. 2010). Further, as the problem space is ever changing, processing speed was an especially robust predictor of written expression and likely accounts for differences in written expression because those who can quickly process basic writing skills and coordinate multiple processes (e.g., attention, organization, speed) would likely be able to focus more cognitive resources on producing and evaluating writing content. Relatedly, although short-term working memory played a more significant role with basic writing skills, it was also a

[2] Cormier et al. 2016 followed the rules-of-thumb for effect size criteria suggested by Evans et al. 2002, p. 251: standardized regression coefficients .10–.29 are classified as moderate; ≥ .30 are classified as strong.

consistent predictor of written expression. Short-term working memory assists with retrieval and encoding of information and coordinating complex ideas while simultaneously checking and monitoring the expressed content for overall logical coherence (Kim and Schatschneider 2017). The efficiency of retrieving ideas is also explained by the consistent small-to-moderate effects of learning efficiency on written expression.

It is important to note that despite the inclusion of cognitive abilities, gender remained a statistically significant predictor of basic writing skills and written expression (with small effects) suggesting a breadth of cognitive abilities did not account for the gender differences (Reynolds et al. 2015). It has been proposed that basic writing skills (transcriptional skills) account for the gender difference in written expression (Berninger et al. 2008; Graham et al. 1997). Although tests of mediation were beyond the scope of the current study,[3] we did find that gender moderated the effects of some specific cognitive abilities on basic writing skills and written expression. Specifically, learning efficiency explained relatively more individual differences in basic writing skills for males at grades 9–12, and processing speed explained relatively more individual differences in written expression for males at grades 9–12. Descriptively, there were stronger regression coefficients between learning efficiency and processing speed and writing outcomes for males (or larger variances accounted for by these cognitive abilities for males). These findings suggest that retrieval abilities and processing speed explain individual differences in achievement scores at upper grades in basic writing skills and written expression, respectively. One explanation is that differences in these abilities translate to better writing products. For example, although females have shown better performance on both timed and untimed writing tasks (Camarata and Woodcock 2006), greater differences in writing performance may emerge for males when more efficient retrieval of information and faster processing is observed. These differences likely manifest in better total word production and overall writing quality (i.e., identifying the correct words to express a particular concept), especially at the upper grade range of schooling when competent writing products are increasingly judged on text production and quality. On the contrary, auditory processing explained relatively more individual differences in written expression for females at grades 9–12. Given females have shown advantages in verbal fluency when writing (Jewell and Malecki 2005; Weiss et al. 2006), auditory processing may play a stronger role in written expression performance for females based on differences in spelling and basic writing skills where "phonological awareness underlies the establishment of the graphemic memory store that is required for written language" (Mather and Wendling 2018, p. 786). Thus, rather than explaining individual differences in performance strictly due to total word production, females may differ at the upper grade ranges based on differences in automaticity with spelling and basic writing skills ostensibly freeing up cognitive resources to allow more focus on expression of content.

Results from the current study offer some implications for practice, though the effects that are found in the current study should be interpreted with caution given the limited research on the neuropsychology of writing (Chittooran and Tait 2005). The findings from this study are based on standardized measures of writing achievement and they reflect to a considerable extent some of the knowledge-telling strategies and efficiency of expression skills that are emphasized in school writing practices (Deane 2018). However, our findings do not account for some of the sociocultural factors that interact with writing (Deane 2018; Graham 2018) and practitioners should consider other important variables (e.g., cultural, motivational resources, social identity) when evaluating writing. While we do not necessarily advocate for a moderator-sensitive psychoeducational assessment practice (i.e., treat scores differently based on specific demographic characteristics of an individual based on research on moderators at a group level), we nonetheless argue that it is informative for practitioners to be sensitive to group differences to understand what may be considered atypical relative to a comparison group. In psychological and neuropsychological evaluations, this may also include assessing cognitive variables that were shown to explain unique variance in basic writing skills and written expression, which may be leveraged in understanding the unique learning needs of students (Schneider and Kaufman 2017). Findings showing how cognitive-writing relationships may be moderated by gender, especially at upper grade levels, may help contribute to the knowledge of some performance differences for each gender.

Limitations and Future Directions

The current study is not without limitations. The focus of the current study was on cognitive explanatory variables of writing achievement. Even though we included additional measures of cognitive ability such as auditory processing and processing speed not used in prior research (e.g., Hajovsky et al. 2018b), other educational variables such as motivation (e.g., self-efficacy for writing), and executive functioning (e.g., inhibition, verbal fluency) have been shown to be important for writing achievement (Berninger et al. 2017; Graham et al. 2017; Hayes and Berninger 2014). Although these variables are likely a part of the tests included on the WJ IV, they are not

[3] In a supplementary mediation analysis, we found that cognitive abilities operated directly on written expression and indirectly via basic writing skills. The gender difference in written expression was mostly negligible when differences in basic writing skills were accounted for first (i.e., the gender difference in written expression is primarily due to basic writing skills in early to middle grades, but not in later grades). Basic writing skills had very large direct effects on written expression (β = .54–.60) across grade levels.

necessarily pure measures of these skills. Thus, future research should include these variables within a more comprehensive explanatory framework to shed light into developmental and gender-related differences. Second, the standardized writing tasks on the WJ IV do not necessarily address the kinds of writing required of middle and high school students such as paragraph and essay writing. Thus, results may have limited generalizability to similar writing tasks, especially for older students. Research using different types of writing tasks that are less structured and have more complex demands may provide some information on whether these results generalize to writing tasks that are commonly assigned to older students. Third, the cognitive ability variables employed within the predictive models are composite scores. While observed composite scores provide information that is directly relevant to practitioners because these are the scores they are often using in practice, latent variable models may strengthen conclusions as there is a closer correspondence to the targeted construct (Benson et al. 2016; Keith 2019). In addition, an assumption of the cognitive ability composites utilized in the current study is that they align with the underlying theoretical structure of the WJ IV. Dombrowski et al. (2018) used the correlation matrices from the WJ IV standardization sample for ages 9 to 13 and 14 to 19 (based on 18 WJ IV COG subtests), and found that four group factors (Verbal, Working Memory, Processing Speed, and Perceptual Reasoning) best fit the data. They suggested the WJ IV may be overfactored and that the proposed structural validity lacks support. Research that employs alternative conceptualizations of the factor structure of the WJ IV when studying cognitive and writing achievement relations is a future area worthy of study. However, as previously noted, psychologists and other clinicians regularly use composite scores to inform their decision making and thus make conclusions regarding their use. This study extends an understanding of how these composite scores operate differently on writing for different groups. Last, results are based on the use of cross-sectional data rather than longitudinal data. While some inferences about gender differences can be reached using cross-sectional designs, future research should utilize longitudinal designs to allow stronger conclusions concerning developmental differences across gender in academic skill development (Hajovsky et al. 2017).

Conclusion

The current research showed some consistent mean differences between genders across cognitive and writing skills, and gender moderated the relationships between some cognitive abilities and writing skills. Females showed consistent average advantages on measures of processing speed and written expression across grade levels. There were gender and developmental differences in the way cognitive abilities associated with basic writing skills and written expression, limiting the generalizability of a single cognitive explanatory model of writing across selected populations. However, much research is needed to elucidate practical implications of these results so there can be concrete recommendations that may inform expectations and assessment practices. Although results were observed within a large, nationally representative sample, the moderation findings should be cross-validated with other samples and measures to provide evidence of constructive replication.

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