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Text Comprehension Mediates Morphological Awareness, Syntactic Processing, and Working Memory in Predicting Chinese Written Composition Performance

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Abstract

The goal of the present study was to test opposing views about four issues concerning predictors of individual differences in Chinese written composition: (a) Whether morphological awareness, syntactic processing, and working memory represent distinct and measureable constructs in Chinese or are just manifestations of general language ability; (b) whether they are important predictors of Chinese written composition, and if so, the relative magnitudes and independence of their predictive relations; (c) whether observed predictive relations are mediated by text comprehension; and (d) whether these relations vary or are developmentally invariant across three years of writing development. Based on analyses of the performance of students in grades 4 (n = 246), 5 (n = 242) and 6 (n = 261), the results supported morphological awareness, syntactic processing, and working memory as distinct yet correlated abilities that made independent contributions to predicting Chinese written composition, with working memory as the strongest predictor. However, predictive relations were mediated by text comprehension. The final model accounted for approximately 75 percent of the variance in Chinese written composition. The results were largely developmentally invariant across the three grades from which participants were drawn.

Keywords

Chinese children's written composition; text comprehension; mediation; working memory; morphological and syntactic processing

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Although humans have been engaged in writing from the time they first began to read, considerably more research has been devoted to the study of reading compared with writing (Wagner et al., 2011). In the late 19th century, studies of reading were relatively common while scientific studies of writing were just beginning to appear sporadically (Bazerman, 2008). In the last couple of decades, a great deal of writing research has been reported (for reviews, see Berninger & Chanquoy, 2012; Graham & Harris, 2009; Grigorenko, Mambrino, & Priess, 2012; MacArthur, Graham, & Fitzgerald, 2006). However, with the exception of a relatively small literature that specifically addresses relations between reading and writing, research on writing and its development has proceeded largely independent of research on reading (Fitzgerald & Shanahan, 2000). In addition, the vast majority of studies on writing are limited to alphabetic writing systems. Finally, more research has been devoted to lower levels of reading and writing (i.e., decoding and spelling) compared to higher levels (i.e., comprehension and composition).

Origins of Individual and Developmental Differences in Writing

If one asks children to produce written compositions, two empirical facts are immediately obvious. First, within a grade or restricted age range, individual differences are pronounced. Some children write fluently, producing longer, complex, and relatively error-free passages. Others write haltingly, and are only able to produce short passages replete with spelling and grammatical errors. The second obvious empirical fact is that developmental differences are obvious in writing samples produced by children from different grades.

The first model of writing to gain acceptance was proposed by Hayes and Flowers (1980). According to the model, writing consisted of three parts: planning what you wanted to say; translating your ideas to print; and reviewing what you are writing. The model did not address individual or developmental differences, but a revision of the model did so indirectly by incorporating cognitive processes such as working memory that supported writing (Hayes, 1996). Individual and developmental differences in these supporting cognitive processes presumably would affect writing.

Several theories of writing were proposed subsequently that directly account for individual and developmental differences. Based on an analogy to the simple view of reading that explains individual and developmental differences in reading comprehension as the interaction between listening comprehension skills and decoding skills (Gough & Tumner, 1986; Hoover & Gough, 1990), Juel, Griffith, and Gough (1986) proposed a simple view of writing in which individual and developmental differences in writing are accounted for by an interaction between quality of ideas and spelling ability. More recent theories of writing have been expanded to reflect the fact that writing operates under cognitive constraints such as limited working memory that presumably also affect reading comprehension as opposed to being uniquely related to writing (Berninger & Winn, 2006; Torrance & Galbraith, 2006).

Relations between Writing and Reading

Although research and pedagogy have viewed reading and writing as separate domains (Shanahan, 2006), when studies have measured both reading and writing the results suggest that reading and writing are closely related (Abbott & Berninger, 1993; Berninger, Abbott, Abbott, Graham, & Richards, 2002; Fitzgerald & Shanahan, 2000; Graham & Harris, 2000; Jenkins, Johnson, & Hileman, 2004; Juel, 1988; Juel et al., 1986; Shanahan, 1984; Tierney & Shanahan, 1991). Correlational analyses of measures of reading and writing indicate that approximately 50 percent of their variance is shared. When multiple indicators are available and latent variables can be used to reduce the influence of measurement error, up to 65 percent of the variance in reading and writing appears to be shared (Berninger et al., 2002; Shanahan, 2006).

It is not surprising that reading and writing are highly related. Writing and reading draw on analogous mental processes and knowledge, including: (a) declarative knowledge (e.g, lexical knowledge of phonemic, graphemic and morphological awareness, syntax and text format); (b) procedural knowledge such as accessing and using general knowledge to integrate various linguistic and cognitive processes; (c) domain knowledge such as vocabulary, semantics and prior knowledge; and (d) meta-knowledge or pragmatics in knowing the interactions of readers and writers and in monitoring one's own knowledge in composing and reading (Fitzgerald & Shanahan, 2000; Foorman, Arndt, & Crawford, 2011). Knowledge about reading might also be applied directly to writing or vice versa. Shanahan and Lomax (1986) compared models specifying reading-to-writing, writing-to-reading, and interactive relations in a study of 2nd and 5th grade students. The reading-to-writing model was superior to the writing-to-reading model, and the interactive model was superior to the reading-to-writing model for 2nd grade. A recent study that modeled the co-development of reading and writing at the word, sentence, and passage level using latent change score modeling found support for a reading-to-writing model at the word and passage levels and for an interactive model at the sentence level (Ahmed, Wagner, & Lopez, in press).

Although reading and writing have much in common, there also are important differences. Reading involves recognition of words whereas writing requires recall as well as spelling. Reading involves recognizing the grammatical structure of a sentence written by an author whereas writing requires generating one's own sentence structures. Finally, reading requires following the arguments and organizational structure used by an author writing passages, whereas writing requires planning and designing argument structures and organizing sentences into coherent paragraphs and paragraphs into coherent documents (McCutchen, 2006). Given these differences, it is not surprising that writing is more difficult than reading.

Relations between English and Chinese Writing Systems

There are obvious differences between the English and Chinese writing systems but less obvious yet equally important similarities. Beginning with the most obvious difference, written English is a morphophonemic alphabet in which an orthography consisting of 26 letters as well as additional numbers and punctuation marks is used to represent all possible words. English is morphophonemic in that spellings represent pronunciation but with deviations that sometimes are attributable to meaning. In contrast, the character set of Chinese approaches 60,000 separate characters. Each character represents a spoken syllable that is a morpheme and often a word. Many of the 60,000 characters are low frequency, representing proper names or archaic words, and one can write or read 99 percent of modern Chinese with 2,400 characters (Schmandt-Besserat & Erard, 2008). But this still represents a difference of about two orders of magnitude compared to the number of letters that must be learned to write English. Grammar, syntax, and punctuation are often ambiguous and free-flowing in Chinese writing (Yan et al., 2012). Spoken Chinese is much more homophonic than is spoken English. Consequently, a large number of characters refers to the same syllable, and it is not possible to determine which of many meanings is intended without considering the surrounding context (Tan, Spinks, Eden, Perfetti, & Siok, 2005).

Turning to similarities, English and Chinese are both writing systems that convey information about pronunciation and meaning. Although it is commonly thought that Chinese characters are largely pictorial representations of concepts absent of pronunciation, approximately 90 percent of Chinese characters include a graphic element that indicates pronunciation along with another graphic element that indicates meaning (Schmandt-Besserat & Erard, 2008). Similarity between writing in Chinese and English is suggested by a study of underlying dimensions of written composition in 160 Grade 4 and 180 Grade 7 Chinese children (Guan, Ye, Wagner, & Meng, 2013). They tested the generalizability of a five-factor model of writing developed by Wagner et al. (2011) from an analysis of English writing samples to Chinese writing samples. They asked the children to write two compositions and used the Systematic Analysis of Language Transcripts (SALT) program (Miller & Chapman, 2001) to code and analyze the data. Guan et al. found that the five-factor model of macro organization, complexity, productivity, spelling and pronunciation, and handwriting fluency that was derived from English writing samples applied equally well to both 4^{th}- and 7^{th}- grade Chinese writers. The 4^{th}- and 7^{th}-grade writers differed in the latent means of the factors but not in the pattern of relations among factors.

Given both important similarities and differences between English and Chinese writing systems, it is difficult to predict in advance which aspects of knowledge about writing learned from the large number of studies of English writing will generalize to writing Chinese. Additional studies of Chinese writing will be necessary if we are to develop a theoretical framework for differentiating aspects of writing that are relatively language general and those that are relatively language specific.

Individual and Developmental Differences in Chinese Writing

Given their role in English composition and differences between the English and Chinese writing systems, three potentially important predictors of Chinese writing are morphological awareness, syntax, and working memory.

Morphological awareness—Morphology is concerned with intra-word and inter-word relations. Morphological awareness has been shown to play an important role in reading comprehension, particularly after controlling for word reading (Kirby et al., 2012; Kuo & Anderson, 2006). Morphological awareness is typically measured by tasks such as: (a) morpheme discrimination in sorting out the odd item in orally presented four two-morpheme words (Packard et al., 2006), (b) morpheme production in producing a two-morpheme word with meaning identical to a target morpheme and another word with meaning unrelated to the target (Shu, McBride-Chang, Wu, & Liu, 2006), (c) morpheme transfer of homophonic two-character morphemes (Packard et al., 2006) and (d) morpheme analogy in generalizing a morphological relation from a pair of words to another pair by analogy (Kirby et al., 2012; Liu & McBride-Chang, 2010).

Because the Chinese language includes many homophones, morphological awareness is of particular importance to Chinese reading and writing (Hao, Chen, Dronjic, Shu, &

Anderson, 2013; Kuo & Andersno, 2006; Liu & McBride-Chang, 2010; Packard et al., 2006; Shu et al., 2006; Zhang et al., 2012). Chinese morphology is predominantly that of morphological compounding. A compound can be defined as a word consisting of two or more words which are subjected to certain phonological and morphographic processes (Fabb, 1998). Chinese children have been shown to have a better developed sense of compounding than their American counterparts (Zhang et al., 2012). Semantic relatedness and types of morphemes in Chinese play different roles at different stages of reading literacy development in Chinese children (Hao et al., 2013). More proficient Chinese language users, compared with less proficient ones, have been shown to generate more two-character compound words from left-headed or right-headed base forms (Leong & Ho, 2008). Examples are: 乐观 (optimistic) and 乐器 (musical instrument) from the base form of 乐. Because creating sentences in Chinese demands choosing appropriate characters and surrounding context to permit the reader to infer the correct morpheme, morphological awareness may be critically important to effective Chinese writing.

Syntactic processing—Even though many Chinese sentences are basically of the subject-verb-object (SVO) type, syntax is less straightforward Chinese compared to English. As an example, the subject in a sentence may not always be expressed. The following simple sentence begins with the verb “downed” in 下雨了。 (“Downed rain already” or “It rained”). As yet another example, the semimorphological marker 被 [*bei*] is meant to express unhappy or unexpected events. It is correct to say: 我們被 [*bei*]人打了。 (“We are [were] beaten by others”) but it is anomalous to use the negation: *我們被 [*bei*]人不打了。 (“We were not beaten by others.”).

Studies relating syntactic processing in Chinese to literacy acquisition are sparse. Yeung et al. (2011) used oral cloze task of the kind “My favorite food is ________.” to gauge syntactic skill. But this is more of a sentence completion task rather than a direct test of syntactic processing. Chik et al. (2012) included several measures of syntactic processing in a study of reading comprehension in grades 1 and 2 Chinese children. In a hierarchical multiple regression equation, age, IQ and Chinese word reading accounted for 64% of the individual variation while composite syntactic skills added a significant 4% of the variation.

Working memory—Working memory is believed to be a key predictor of written composition because it provides the cognitive workspace in which writing processes are carried out (Abbott, Berninger, & Fayol, 2010; Berninger & Winn, 2006; Hayes, 1996, 2006; Hoskyn & Swanson, 2003; Kellogg, 1996, 1999, 2001, 2004; Kellogg, Whiteford, Turner, Cahill, & Mertens, 2013; McCutchen, 2000, 2011; Swanson & Berninger, 1996; Torrance & Galbraith, 2006; Vanderberg & Swanson, 2007). For example, Swanson and Berninger (1996) found working memory to be significantly correlated with writing after partialling out word knowledge. In particular, children with high memory span may allocate more resources to generating text rather than to transcription processes such as handwriting and spelling. Abbott et al. (2010) showed consistent and significant relations from spelling to text composing in their five-year longitudinal study, relations that were explained using the construct of working memory. Children with strong spelling skills required fewer memory resources to translate ideas into written words and compositions than did children with weak spelling skills; more working memory resources were available to strong spellers relative to weak spellers to be applied to higher-level aspects of writing.

Working memory is involved in transcribing and editing during writing as shown in a study by Hayes and Chenoweth (2006), who used articulatory suppression to place an additional load on working memory in a study of college undergraduates. The results were that participants in the articulatory suppression condition wrote more slowly and make significantly more errors compared to participants in a control condition.

Predicting Chinese Writing at the Latent Construct Level

In general, there is a paucity of research on individual and developmental differences in Chinese writing. Most of the previous studies on predictors of Chinese writing have largely focused on relatively lower level skills such as character writing quality (Bi, Han, & Zhang, 2009; Guan, Liu, Ye, Chan, & Perfetti, 2011; Guan et al., 2013; Perfetti & Guan, 2012; Tan et al., 2005). For example, Tan et al. (2005) examined relations between reading and writing Chinese characters for groups of beginning and intermediate readers. Partial correlations between reading and writing after controlling for nonverbal intelligence were .50 ($p < .001$) and .47 ($p < .001$) for beginning and intermediate readers, respectively. However, the cross-sectional and correlational design of the study precluded determining the directionality of these relations (Bi et al., 2009).

More recently, Yan et al. (2012) reported a longitudinal study of writing at the passage level as opposed to the level of the individual character. In their study, the writing quality of nine-year-old Chinese students was predicted by earlier measures of vocabulary knowledge, Chinese word dictation, phonological awareness, speed of processing, speeded naming, and handwriting fluency were all significantly associated with writing, after controlling for age.

A limitation of the studies of predictors of Chinese writing just described, as well as many studies of English writing, is that the constructs were represented by single observed variables as opposed to latent variables with multiple indicators. When constructs are represented by single observed variables, the obtained correlation and regression coefficients are affected by measurement error and method variance. One consequence is that measurement error and method variance can make it appear as though the constructs are distinct from one another, when in fact, they all are measuring an identical underlying construct such as language or verbal aptitude. Conversely, when constructs are represented by latent variables with multiple indicator, the effects of measurement error and method variance can be reduced or eliminated depending on the design of the study.

Several studies have begun to look at predictors of Chinese writing at the latent variable level. For example, in a study of component processes in language literacy in 361 fifteen-year-old Chinese students, Leong and Ho (2008) used stimulus cartoon pictures to elicit students' essay writing. They also obtained measures of morphological processing, character and word correction, text segmentation, dictation, copying words and text, text comprehension, oral reading and reading fluency. Exploratory factor analysis was used to examine underlying dimensions of task performance. Six components accounted for 67 percent of the total variance, with half of the variance accounted for by the component of lexical knowledge. This consisted of morphological processing, correct usage of lexical items, segmentation of text passages and writing to dictation. These patterns were largely validated in a confirmatory factor analysis with a new group of 1,164 fifteen-year-old Chinese students (Leong, Ho, Chang, & Hau, 2013). The strongest correlations among factors were obtained for correlations between the reading and writing factors.

The Present Study

The goal of the present study was to test opposing views about four issues concerning predictors of individual differences in Chinese written composition: (a) Whether morphological awareness, syntactic processing, and working memory represent distinct and measureable constructs or are manifestations of general language ability; (b) whether they are important predictors of Chinese written composition, and if so, the relative magnitudes and independence of their predictive relations; (c) whether observed predictive relations are mediated by text comprehension; and (d) whether these relations vary or are developmentally invariant across three years of writing development.

1. Distinct and measureable constructs in Chinese or just manifestations of general language ability?

Based on the existing literature of predictors of writing in English, and on the nature of the Chinese writing system, morphological awareness, syntax, and working memory are potentially important predictors of Chinese written composition. However, because previous studies typically have included only one of these constructs, and the constructs have been represented as single indicator observed variables, it remains important to determine whether these are meaningful distinct and measureable constructs as opposed to simply measures of general language ability. This issue was addressed in the present study by measuring each construct with multiple indicators that then using confirmatory factor analysis to test alternative models, one of which posited a three factor model with morphological awareness, syntactic processing, and working memory as distinct yet potentially correlated abilities, another of which posited a single factor model representing general language ability.

2. Important predictors of Chinese written composition, and if so, what are the relative magnitudes and independence of their contributions to prediction?

Although there is a theoretical rationale for expecting morphological awareness, syntactic processing, and working memory to be important predictors of Chinese written composition, the empirical evidence is scant. Only two studies have used morphological processing as a predictor or writing in Chinese (Leong & Ho, 2008; Leong et al., 2013). No studies have used syntax or working memory as a predictor of Chinese writing. By including all three constructs as predictors in the present study, it was possible to determine (a) whether each was an important predictor of Chinese written composition, (b) the relative magnitudes of their predictive relations, and (c) whether their contributions to predictions were independent or redundant. Bivariate relations between latent variables representing each of the three predictors and the criterion were used to determine whether each was an important predictor of Chinese written composition. We used dominance analysis (Azen & Budescu, 2003; Budescu, 1993) to compare the relative magnitude of these predictive relations. We used structural equation models that included all three constructs as simultaneous predictors to determine whether their contributions to prediction were independent or redundant. It would be possible to each construct to be distinct, yet for their predictive relations to Chinese written expression to be redundant if the reason they were predictive of writing was because they were correlated with general language ability and language ability in turn predicted writing. Alternatively, each construct could be capturing different aspects of language that were independently related to writing.

3. Are any observed predictive relations mediated by text comprehension?

Because of similarities and differences between reading and writing, predictive relations between the three key constructs of morphological awareness, syntactic processing, and working memory and the dependent variable of Chinese written composition might be mediated by text comprehension. Individual and developmental differences in morphological awareness, syntactic processing, and working memory have been shown to be important predictors of reading, although much of this research is limited to reading alphabetic writing systems. However, because of the constructive nature of writing, they may be involved in writing to a greater extent than they are in reading. In the present study, we compared alternative models that proposed that predictive relations between morphological awareness, syntactic processing, and working memory were (a) unmediated, (b) partially mediated, or (c) fully mediated by text comprehension.

A variable is a mediator “to the extent that it accounts for the relationship between the predictor and the criterion” (Baron & Kenny, 1986, p. 1176). According to Baron and Kenny, three conditions must be met to establish M as a mediator of the predictive relation between X and Y: (1) X must significantly predict Y; (2) X must significantly predict M; and (3) M must significantly predict Y controlling for X. Complete mediation is said to occur when the direct effect of X on Y decreases to zero with the addition of potential mediator M. Partial mediation is said to occur when the direct effect of X on Y decreases nontrivially but not to zero with the addition of potential mediator M. No mediation is said to occur when the direct effect of X on Y is substantially unchanged with the addition of potential mediator M.

To test for mediation, we used the two models represented in Figure 1. Figure 1a depicts a structural equation model that specifies morphological awareness, syntactic processing, and working memory as predictors of writing. Fitting this model to the data provides estimates of the unique contributions to prediction of writing made by the three constructs. Figure 1b depicts a structural equation model in which text processing has been added as a mediating latent variable. The mediating relations are represented by the indirect effects from each of the three predictors through text comprehension to writing. The magnitude of the direct effects from the three predictors to writing in Figure 1b after the mediator variable of text comprehension is added determines whether there is evidence for full, partial, or no mediation. Full mediation would be indicated if the direct effects are no longer significantly greater than zero. Partial mediation would be indicated if the direct effects are significantly less than they were in the unmediated model but remain significantly greater than zero. No mediation would be indicated if there are no significant differences between the magnitudes of the direct effects for the mediated and unmediated models.

4. Developmental differences or invariance?

In a previous study of the underlying dimensions of Chinese written composition, a five factor model of individual differences in written composition that originally was developed from analyses of English writing samples produced by first- and fourth-grade students was found to generalize to Chinese writing samples produced by fourth- and seventh-grade students (Guan et al., 2013; Wagner et al., 2011). These studies suggest surprising consistency in the underlying dimensions of written composition across grade and language. However, neither of these studies examined predictors of written composition. As such, they are not informative about whether predictive relations between morphological awareness, syntactic processing, and working memory vary developmentally or are relatively invariant. In the present study, we analyzed the data separately by grade to examine invariance in our measurement model and in relations among constructs across the developmental range represented by fourth through sixth grades.

The present study differs from a recently published paper by Guan, Ye, Meng and Leong (2013) which drew on a subset of poor readers and writers from the same large data pool. That study examined the transactional process of Chinese reading-writing difficulties and used similar cognitive and linguistic tasks. That study showed from hierarchical multiple regression analyses that verbal working memory contributed to individual variation in written composition by poor text comprehenders but not good readers. The study also provided insight into the quality of the students' writing from a qualitative analysis of some sample written compositions. As discussed in this section, the emphasis of the present paper was on the relative magnitude of predicting individual differences in Chinese written composition by the constructs of morphological awareness, syntactic processing and working memory; and on the predictive relations mediated by text comprehension.

Method

Participants

A total of 749 students took part in the study. They were recruited to participate in a larger longitudinal study about assessment and intervention of writing disabilities (Grant # DBA120179) and Chinese writing model (Grant#YJ2012-019) conducted by the first author. These participants were drawn from Grades 4, 5, and 6 in one primary school in Ningbo, Zhejiang Province, China. According to the municipal educational bureau report, the students' parents' average annual salary was about 25,000 USD, their demographic information and social economic status are representative of the middle class in China (NIES, 2012). Their parents signed the informed consent form before their children actually participated in this study. There were 246 Grade 4 students from six classes (n_{boy} =142, n_{girl} = 104, M_{age} = 9.76, SD_{age}= 0.84), 242 Grade 5 students from six classes (n_{boy} =129, n_{girl} = 113, M_{age} = 11.01, SD_{age}= 0.84), 261 Grade 6 students from six classes (n_{boy} =155, n_{girl} = 106, M_{age} = 12.31, SD_{age}= 0.70). For the total sample, the mean age was 11.05 years (SD = 1.32 years). To assess the possible dependence among the students within a class, we calculated the intra-class correlation for the three writing variables and found the nesting effect was minimal (ICCs < .047). Thus, we proceeded with the analysis by treating these students as independent.

The group tasks were administered in the classrooms of the students. Three full-time and nine part-time Chinese-speaking research assistants were given several days' intensive training on the rationale of the project, the reasons and designs of all the tasks, and specifics of administration before their field work in the school. These experienced assistants were carefully supervised by the first author to ensure high fidelity of data collection.

Tasks and Procedure

Multiple indicators were obtained to provide latent variables representing five constructs:

Written composition (WC)—We asked the children to write three kinds of compositions: narration, argumentation and exposition. These kinds of writing are representative of important writing tasks (Berman & Nir-Sagiv, 2007; Britton, 1994). Narratives focus on people, their action, motivation and events unfolding in a temporal sequence; expository compositions focus on issues with ideas unfolding in logical structure. Different from narrations and expositions, argumentation compositions require writers to argue and counter-argue, all based on plausibility and factual information (Reznitskaya, Anderson, & Kuo, 2007). These written compositions were scored according to the three aspects of expressiveness, content and commentary.

Narrative writing (WNar) was produced in response to four black-and-white line drawing cartoons without words and titles from Leong and Ho (2008). These cartoons have a universal appeal to all ages and can be interpreted flexibly from different perspectives. There were four basic elements in the cartoons: a boy reading while a girl is coming forward; a boy and girl in conversation; the two children having different opinions with an ensuing argument; the girl getting away and the boy falling. From these simple but integrated themes the students were asked to write short compositions from their personal experience to construct a textbase to describe the scenes and to express their meaning and emotion (see Kintsch & Kintsch, 2005). They should also provide appropriate discussion and a title. This task was given to groups of students in 20 min and they were requested to write individually between 150 and 500 words. A total score of 100 was given to each student. Scoring was by two research assistants according to expressive aspects (40% of total score), content including title (40% of total score) and commentary (20% of total score). Expressive aspects included total number of words, total number of new words, word choice of low frequent vocabulary, and lexical density. The content included four aspects of topic, main idea, body and conclusion. Commentary included two aspects of objective discussion and subjective comments on the theme of writing. Any disagreement on scoring was re-examined by a third assistant and resolved accordingly. Inter-rater reliability of the original two scorers represented by the Pearson product-moment coefficient for the task was .85, and test-retest reliability was .75.

Argumentation writing (WArg) was on the advantages and disadvantages of watching television for elementary school children. Students were asked to state the pros and cons of watching television, and give reasons with examples to illustrate their points. They were also instructed to provide appropriate discussion for each point. Similar to expository writing, this task was administered to groups of students who were given 20 minutes to write compositions of between 150 to 500 words. The scoring procedure was the same as the narrative writing task. Inter-rater reliability for the task as a whole was .88, and test-retest reliability was .76.

Expository writing (WExp) was writing on the topic of "My Favorite Pet/Toy." Students were asked to name one of their favorite pets (or toys if there were no pets) and describe their detailed features and other interesting characteristics. This task was also given as a group-administered writing task in 20 minutes with students being requested to write individually between 150 and 500 words. The scoring procedure was the same as the other two writing tasks. Inter-rater reliability for the task was a whole was .78, and test-retest reliability was .86.

Text comprehension (TC)—Eight short text passages were adapted from Leong, Tse, Loh, and Hau (2008) and rewritten in simplified Chinese characters. Four of the eight text passages were narrative pieces, and the other four were expository essays. These 8 short essays were carefully balanced in syntactic complexity, ranged in length from 6 sentences to 13 sentences, and the contents were all of interest to children between the ages of 9 to 12. An example was the passage "Alfred Nobel" which gives an account of the contribution of the inventor and Nobel Prizes and contains 8 sentences (2 simple and 6 compound sentences). These 8 passages were followed by three written open-ended comprehension questions each. The questions drew on higher-order thinking such as hypothesizing, using schemata, questioning, citing evidence, verifying ideas and integrating them.

The text comprehension task was administered to the students as a class in 40 minutes plus 10 minutes for two short practice examples to explain the task. In one practice example with three sentences the translated text is as follows: "One cold winter day, a group of displaced persons arrived at the small town. They were ghastly pale and utterly exhausted. The people of the small town cooked them hot meals." In the first of the two questions the children were asked to discuss verbally what they would do if they were the displaced persons and given free food. The whole class was asked to give the "best" answers and was told these would be graded according to the depth of meaningfulness of the answers from a credit of 3, to 2, then 1 or 0 for an irrelevant or implausible answer. An answer such as "I will say 'thank you' and eat the food" was given a score of 1. An answer such as "I will say 'thank you' but also offer to do some work in return before taking food from strangers" was given a score of 3. The maximum score for the whole task was 72 (8 passages ×3×3).

The principles of scoring the written answers were on the basis of problem solving and transforming knowledge and not merely telling it (Bereiter & Scardamalia, 1987, p. 341), of explanatory and not just descriptive or factual answers, and of "envisionment" of text-worlds (Langer, 1986). The children were further told to work quickly and to concentrate on making meaning and not worry about sentence construction and spelling since they had to read the 8 passages and to write the answers to all the 24 open-ended questions on the protocols in the span of 40 minutes.

To ensure consistency of grading, each set of written protocols was marked by two research assistants according to the grading principles explained above. Inter-rater reliability for the protocols for the 8 passages as a whole was .91. This coefficient indicates that the 8 passages as a whole and the answers to the comprehension questions were consistent and useable. The mainly narrative texts (Passage Nos. A1, 2, 3 and 4) based on genre and structure constituted one indicator text comprehension 1 (TC1). Cronbach alpha was .77. The mainly expository texts (Passage Nos. B 5, 6, 7 and 8) formed the second indicator text comprehension 2 (TC2). Inter-rater reliability for this TC2 was .78, and test-retest reliability was .81.

Working memory (WM)—The working memory construct was represented by two tasks: a verbal span working memory task (VSWM) involving unrelated sentences and an operation span working memory (OSWM) task involving numbers and very simple Chinese words.

A verbal span working memory (VSWM) task was adapted from that used by Leong et al. (2008) and Leong and Ho (2008). It was based on the rationale and format of Daneman and colleagues (Daneman & Carpenter, 1980; Daneman & Merikle, 1996) as modified by Swanson (1992). Six sets of two, three and four sentences, all unrelated in meaning, were read orally by the experimenter to groups of students. They first listened to each set of two-, three-, or four-sentences plus a comprehension question, all spoken in Putonghua; and were then to write down on designated forms their short answers to the comprehension question and the last word in each sentence of the set. The total testing time for this task was 20 minutes and all the answers were scored independently by two RAs. One point was awarded for each correct answer and the maximum score was 24. Inter-rater reliability for the task was .83, and test-retest reliability was .77.

An operation span working memory (OSWM) task was modeled after the operation span task of Engle, Tuholski, Laughlin, and Conway (1999). Groups of students heard 6 sets of 3 or 4 sentences, each of which involved very simple mental arithmetic calculation with either a correct (YES) or wrong (NO) answer and followed by a simple spoken word. Students had to wait till the end of each sentence set before writing down on the designated forms just YES/NO to the answers of the simple calculation and the one word at the end in the correct order. An example of a three-sentence set is as follows: “Is 16 − 9 = 7? (Bear) <u>YES</u>/NO; Is 12 × 2 = 24? (Bus) <u>YES</u>/NO; Is 20 − 6 = 12? (Book) YES/<u>NO</u>.” The total testing time for this task was 15 minutes and the maximum score was 21. Inter-rater reliability for the task was .98, and test-retest reliability was .76.

Morphological awareness (Morph/MP)—There were two indicators for this construct: a morphological compounding (MorCom/Morph1) task from Leong and Ho (2008) and a morphological chain (MorCha/Morph2) task.

A morphological compounding (MorCom) task contained two parts that varied in generating left-headed or right-headed two-character morphological compound words with 8 base items each for a total group administration time of 12 minutes. Students could freely choose any 5 base forms to produce as many “right-headed” two-character words in the available time, and any 6 base forms to produce as many “left-headed” two-character words in the total time of 6 minutes allotted. Two research assistants scored the freely affixed items to the base forms. Inter-rater reliability was .83, and test-retest reliability was .79. The Cronbach Alpha internal consistency reliablity of all the items for this measure was .70.

A morphological chain (MorCha) task required the participants to provide as many different two-character compound words from the left-headed base character as possible in 5 minutes' time. The constraint was that the same base form and homophonic base forms could not be repeated. Two research assistants scored the freely affixed items to the base forms. Inter-rater reliability was .98, and test-retest reliability was .82. Cronbach Alpha was.74.

Syntactic processing (SP)—Syntactic processing plays an important role in helping language users to understand the appropriate relationship between topics and comments and the interpretation of the sentence. A topic is what the sentence is about; and the comment is the rest of the sentence separable from the topic by a pausal marker. A topic sets a “spatial, temporal, or individual framework within which the main prediction holds” (Li & Thompson, 1989, P. 85). Syntactic processing is thus an interactive process with lexical knowledge and sentential context mutually influencing each other. There were two tasks: syntax construction and syntax integrity.

A syntax construction (SynCon) task consisted of ten scrambled sentences scrambling mostly two-character words. Students were asked to recombine the words in the scrambled sentences to come up with the correct sequence of the lexical items to make the sentences grammatically correct in the recombination. The administration time was 20 min. All the answers were scored by two research assistants. Inter-rater reliability was .88, and test-retest reliability was .80. Cronbach alpha of the internal consistency of all the items for this measure was .71.

A syntax integrity (SynInt) task required error detection and correction. The syntax integrity task assessed the students' understanding and correct usage of syntactic structure. The students were asked to read each of the 20 short grammatically anomalous sentences, detect the error in the syntactic pattern and to correct that error. There were twenty sentences and the testing time was 25 minutes. All the answers were scored by two research assistants. Inter-rater reliability was .92, and test-retest reliability was .81. Cronbach alpha of the internal consistency of all the items for this measure was .82.

Procedures

The tasks were administered to groups of students over three consecutive days. The verbal span working memory task, morphological compounding task, text comprehension1, and narrative writing task were administered on day one. The syntax construction task, text comprehension2, and argumentation writing task were administered on day two. The syntax integrity task, the morphological chain task, the operation span working memory task, and expository writing task were administered on day three. Instructions for each task were audio-taped and played to the students groups, so that all the tasks were administered uniformly across groups.

Data Analysis

The data analysis was carried out in three stages after data screening as follows.

Confirmatory factor analysis—The first stage was to assess the construct validity and measurement invariance of the proposed latent variables. At this stage, we first conducted confirmatory factor analysis (CFA) for each of Grades 4, 5, and 6. In each CFA model, one of the factor loadings for each factor was fixed to be one for scale dependency in model identification. In the second step, we assessed measurement invariance across grades. The purpose of testing measurement invariance was to establish that either partial- or full-measurement invariance was established across grades. Failing to do so would preclude meaningful comparisons across grades because of concern that the latent variables were not comparable.

There are several forms of invariance in their procedure. Here we tested metric invariance (equal factor loadings) and scalar invariance (equal intercepts) using multi-group CFAs. Metric invariance is required for comparing latent means, while there is debate on whether scalar invariance is needed (Polyhart & Oswald, 2004). A stepwise procedure was adopted to assess measurement invariance (Vandenberg & Lance, 2000): 1) A baseline model was analyzed without any equality constraints for corresponding factors; 2) an equal factor loading model was analyzed with equality constraints imposed on corresponding factor loadings (metric invariance). If all factor loadings were invariant, we continued to 3) assess invariance of intercept (scalar invariance). If all factor loadings were not invariant, we found out which variables had equal factor loadings and then among these variables, which had equal intercepts. The chi-square difference test was used to assess the invariance of factor loadings and intercepts. Chi-square difference testing was conducted using the Satorra-Bentler adjusted chi-square (Satorra, 2000; Satorra & Bentler, 1988). With measurement invariance established, latent means were compared across grades with latent standardized effect sizes reported (Choi, Fan, & Hancock, 2009).

Structural equation models—The second stage of data analysis consisted of testing alternative structural models to estimate the strength of predictive relations between morphological awareness, syntactic processing, and working memory as predictors of written composition, and the potential mediating effects of text comprehension on these predictive relations. Chi-square difference testing was used to compare results across grades.

For the CFA and SEM analyses, the goodness of fit between the data and the specified models was estimated by employing the Comparative Fit Index (CFI) (Bentler, 1990), the Tucker Lewis Index (TLI) (Bentler & Bonett, 1980), the Root Mean Square Error of Approximation (RMSEA) (Browne & Cudeck, 1993), and the Standardized Root Mean Square Residual (SRMR) (Bentler, 1995). CFI and TLI guidelines of greater than 0.95 were employed as standards of good fitting models (Hu & Bentler, 1999). Different criteria are available for RMSEA. Hu and Bentler (1995) used .06 as the cutoff for a good fit. Browne and Cudeck (1993) and MacCallum, Browne, and Sugawara (1996) presented guidelines for assessing model fit with RMSEA: values less than .05 indicate close fit, values ranging from .05 to .08 indicate fair fit, values from .08 to .10 indicate mediocre fit, and values greater than .10 indicate poor fit. A confidence interval of RMSEA provides information regarding the precision of RMSEA point estimates and was also employed as suggested by MacCallum, Browne, and Sugawara (1996). A SRMR <.08 indicates a good fit (Hu & Bentler, 1999). All CFA and SEM analyses were performed with Mplus 6.1 (Muthén & Muthén, 2010).

Dominance analysis—The third stage of data analysis consisted of dominance analysis (Azen & Budescu, 2003) to assess the unique contribution and relative importance of morphological awareness, syntactic processing, and working memory in accounting for variance in written composition. For the dominance analysis, the dependent variable written composition was calculated as the sum of standardized scores of the three writing tasks. The predictors, working memory, morphological processing, and syntactic processing were also calculated as the sum of the standardized scores of the corresponding tasks.

The purpose of dominance analysis is to address the problem that the relative importance of correlated predictors is affected by the other predictors included in or excluded from the model (Cohen, Cohen, West, & Aiken, 2003; Courville & Thompson, 2001). Common measures of relative importance, including standardized regression coefficient, zero-order correlation, partial correlation, semi-partial correlation, are affected by this phenomenon. More recently, dominance analysis, developed by Budescu (1993) and refined and extended by Azen and Budescu (2003), presents a better alternative for analysis of predictor importance, which provides a general approach to measure relative importance in a pairwise fashion in the context of all models that contain some subsets of the other predictors (Azen & Budescu, 2003). Dominance analysis is able to answer the key question of predictor importance: "Is variable X_i more or less (or equally) important than variable X_j in predicting Y in the context of the predictors included in the selected model?" (Azen & Budescu, 2003, p. 145).

Several measures of dominance were introduced that differ in the strictness of the dominance definition. Here we adopted the strictest definition of dominance, complete dominance. We illustrate this with three predictors (X1, X2, X3), as in the current study, to predict one criterion variable. All possible model combinations of predictors were examined, including 3 subset models with only one predictor, 3 models with two predictors, and one model with all four predictors, resulting in a total of 7 subset models. Predictor X1 is said to have complete dominance over predictor X2 when unique variance contribution of Predictor X1 is greater than Predictor X2 in each of the subset models to which both X1 and X2 could make additional contribution, i.e., the null model without any predictor, and the model with X3.

To generalize dominance results beyond the studied sample, we followed Azen and Budescu (2003) in calculating the standard error of dominance across repeated sampling and the reproducibility of the present dominance in the population. Let D_{ij} denote a measure of dominance, which equals 1 if X_i dominates X_j, equals 0 if X_j dominates X_i, and .5 if dominance cannot be established between the two predictors. A distribution of D_{ij} could be simulated by obtaining this measure over many (e.g., 1,000) repeated samples with replacement, which are generated using the bootstrap procedure. The average of these dominance values over all bootstrap samples, $\overline{D}_{ij}$, represents the expected level of dominance of X_i over X_j in the population. The standard error of D_{ij}, $SE(D_{ij})$ is the standard deviation of D_{ij} over all bootstrap samples. $\overline{D}_{ij}$ closer to 0 or 1indicates a strong case for a clear directional dominance, while that close to .5 suggests indeterminacy of dominance. The percentage of the bootstrap samples that replicates a dominance of, for example, X_i over X_j, in the studied sample is termed reproducibility, which states the probability that X_i dominates X_j and determines a confidence level on that probability.

Results

Preliminary Analyses

Table 1 displays the means, standard deviations, skewness, and kurtosis of the various measures used in the study by grade level. In addition, the Shapiro-Wilk's test was used to examine the normality of these measures. Several variables were not normally distributed, and there were moderate ceiling effects for operational span working memory. The assumption of multivariate normality was violated, Mardia's skewness = 75.04, $p < .001$, and Mardia's kurtosis = 156.65, $p< .001$. To address the non-normality, Sartorra-Bentler correction was implemented for both model fit and parameter estimation by using maximum likelihood with robust standard errors (MLR) estimation. Table 2 presents the intercorrelations of these measures by grade.

Confirmatory Factor Analyses

The results of confirmatory factor analyses carried out by grade using the 11 tasks as indicators of the latent variables indicated that the five latent factors were measured well with these tasks for each grade. Specifically, the fit of the confirmatory factor model was satisfactory for grade 4, $\chi^2(34) = 90.57$, $p <$ 001, RMSEA = .08 with 90% confidence interval (.06, .10), CFI = .96, TLI = .93, SRMR = .04; satisfactory for grade 5, $\chi^2(34) = 79.54$, $p < .001$, RMSEA = .08 with 90% confidence interval (.06, .10), CFI = .96, TLI = .94, SRMR = .03; and satisfactory for grade 6, $\chi^2(34) = 94.62$, $p < .001$, RMSEA = .08 with 90% confidence interval (.06, .10), CFI = .96, TLI = .93, SRMR = .04. Table 3 presents the standardized factor loadings and the correlations among factors. The correlations between the three predictors of morphological awareness, syntactic processing, and working memory and the criterion of written composition were substantial at each grade level, ranging from a low of .57 to a high of .79.

The adequate model fits and the moderate correlations between the three predictors of morphological awareness, syntactic processing, and working memory supported the view that these represent distinct and measurable abilities. The alternative view that they are just manifestations of a single underlying factor of general language ability was tested by a model that represented the indicators of morphological awareness, syntactic processing, and working memory as indicators of a single general language factor. This model resulted in a significantly poorer fit at each grade, with $\Delta\chi^2$ values of 65.32. 134.27, and 88.68 for grades 4, 5, and 6 respectively, all significant at $p < .001$ for $\Delta df = 7$.

We examined the measurement invariance between grades using multi-group CFA (see Table 4). The baseline model resulted with a good fit. The model with equal loadings resulted with a significantly poorer fit. We examined each variable individually, and found that narrative writing (WNAR) had a different loading for grade 5. We further tested the invariance on intercepts and found that the model with equal intercepts resulted in a significantly poorer fit. We examined each variable individually, and found that operational span working memory (OSWM) had a different intercept for grade 5, and text comprehension task 2 had a different intercept for grades 5 and 6. These results suggest that partial measurement invariance held across grades.

Table 5 presents the latent means and variances of the five factors for each grade. The fifth graders had significantly higher means than the fourth graders, and the sixth graders had significant higher means than the fourth and fifth graders (ps $< .001$). The latent standardized effect sizes (Choi et al., 2009) for pairwise comparisons on the latent means (as shown in Table 5) suggested that the mean difference was medium between grades 4 and 5, small to medium between grades 5 and 6, and large between grades 4 and 6.

In summary, the results indicated that the latent variables were well measured by their indicators. Measurement invariance was largely supported, allowing us to compare latent means across grades. Sixth grade students had significantly higher means than the fifth-grader students, who in turn had significantly higher means than the fourth grade students.

Structural Equation Modeling

Structural equation models were used to examine hypothesized relations among the measured constructs (presented in Figure 1). We fit the model simultaneously to all three grades while constraining the factor loadings (except WNAR for grade 5) and intercepts (except OSWM for grade 5, and text comprehension task 2 for grades 5 and 6) equal across grades as supported by the measurement invariance results. We first fit a model that specified morphological awareness, syntactic processing, and working memory as predictors of written composition. This model provided an excellent fit, $\chi^2_{(df=81)} = 140.09$, $p < .001$, CFI = .98, TLI = .97, RMSEA = .05 (90% CI: .04–.06), and SRMR = .04. We then added text comprehension as a mediating variable and reestimated the model. This model provided a satisfactory fit, $\chi^2_{(df=122)} = 334.21$, $p < .001$, CFI = .95, TLI = .93, RMSEA = .08 (90% CI: .07–.09), and SRMR = .05. The results from these two models are presented by grade in Table 6.

The first column presents bivariate latent variable correlations. Squaring these correlations gives an estimate of the shared variance between each predictor and written composition. The second column presents structure coefficients that were obtained when the latent variables were used as simultaneous predictors of written composition. The coefficients represent the independent contributions to prediction for each predictor. The third column presents structure coefficients for the predictors after text comprehension was added to the model as a potential mediator. The extent to which these structure coefficients were reduced compared to those without the mediator in the analysis indicates whether full, partial, or no mediation was occurring. The final two columns present estimate and bias corrected bootstrap 95% confidence interval of indirect effects of the predictors on written composition via the mediator variable of text comprehension. Significant indirect effects, noted by confidence intervals not containing zero, provide evidence of mediation.

The results of the first set of structural equation analyses indicated that morphological awareness, syntactic processing, and working memory were related to written composition individually, and made independent contributions to prediction when considered as simultaneous predictors. When text comprehension was added as a potential mediator, the overall pattern of results was consistent with complete mediation. The predictive relations between the three predictors and written composition approached zero when text comprehension was added as a mediator. The bootstrap 95% CI indicates that the mediation effect was significant for grades 5 and 6, while marginally significant for grade 4 (90% CI did not contain zero). The model accounted for approximately 75 percent of the variance in written composition.

Figures 2 to 4 present the standardized path coefficients of the mediation model (as in Figure 1.b) for the three grades. A chi-square difference test was conducted to examine whether each path was equal across grades (see Table 7). All paths were found equal except the path from working memory to text comprehension, which was found equal between grades 5 and 6, but not between grades 4 and 5 ($p = .04$) nor between grades 4 and 6 ($p = .003$).

In summary, the results of structural equation models supported complete mediation of the effects of morphological awareness, syntactic processing, and working memory on written composition via text processing. The results were largely consistent across grades.

Dominance Analysis

Table 8 presents the unique contribution in terms of proportion of variance explained by the four variables predicting written composition. The first column contains the total R^2 for the corresponding subset model, and the remaining columns report the unique variance contribution added to that subset model. For example, for grade 4, the subset model with WM demonstrates that 34% of written composition variance was accounted for by WM. After controlling for WM, the unique contribution to variance was 14% for MP and 8% for SP. In the subset model of WM-MP, the two predictors jointly accounted for 48% of variance, with 3% unique variance added by SP. Based on these unique contributions, we calculated the average contribution of a predictor as the mean of its average contribution over the subset models with the same number of predictors (Budescu, 1993). For all three grades, WM was the strongest predictor of written composition, uniquely contributing, on average, 20.67% of the variance for grade 4, 17.00% of the variance for grade 5, and 24.17% of the variance for grade 6. This was followed by MP (Grade 4: 18.83%; Grade 5: 12.50%; Grade 6: 12.17%) and TC (Grade 4: 11.67%; Grade 5: 11.67%; Grade 6: 9.67%).

In Table 9, the first and second columns identify the two variables being compared; the third column is the value of dominance measure D_{ij}, in the sample; the fourth column is the average value ($\overline{D}_{ij}$) over the 1,000 bootstrap samples, and the fifth column is the standard error of the D_{ij} values. The next three columns describe the distribution of D_{ij} over the 1,000 bootstrap samples, where P_{ij} is the proportion of samples in which X_i dominates X_j, P_{ji} is the proportion of samples in which X_j dominates X_i, and P_{noij} is the proportion of samples in which the dominance could not be established. The last column is the reproducibility of the sample results, i.e., the proportion of bootstrap sub-samples that agree with the tested sample results.

Examining the sample dominance values and reproducibility indices, working memory dominates morphological processing with high reproducibility for grades 5 (82%) and 6 (98%), and with low reproducibility for grade 4 (56%). Working memory dominates syntactic processing for all three grades with high reproducibility (92% for grade 4, 83% for grade 5, and 93% for grade 6). The sample suggests that morphological processing dominated syntactic processing for grade 4 (with 90% reproducibility), but undetermined for grades 5 and 6.

In summary, the results of dominance analysis were that working memory dominated syntactic processing for all grades. For Grade 4, morphological awareness dominated syntactic processing. For grades 5 and 6, working memory dominated morphological awareness. The other pairwise comparisons on unique contribution did not suggest reproducible dominance relationship.

Discussion

The goal of the study was to test opposing views about four issues concerning predictors of individual differences in Chinese written composition. We discuss results that address each issue before turning to limitations of our study and issues that are important to be addressed in future research.

1. Distinct and measureable constructs in Chinese or just manifestations of general language ability?—Because previous studies typically represented morphological awareness, syntactic processing, and working memory as single indicator observed variables and did not include all three constructs, an important first step was to determine whether they represented distinct constructs or were merely manifestations of general language ability. We did this in the present study by including all three constructs and representing each as a latent variable with multiple indicators.

Based on the adequate model fits obtained for confirmatory factor analysis models that specified them as distinct yet potentially correlated abilities, and the fact that the obtained factor correlations ranged from .35 to .67, the results support morphological awareness, syntactic processing, and working memory as distinct yet correlated constructs, as opposed to just manifestations of general language ability. A single factor model specifying that the indicators of morphological awareness, syntactic processing, and general language ability were indicators of general language ability resulted in substantially and significantly poorer model fits. The results then supported the view that morphological awareness, syntactic processing, and working memory are distinct and measurable constructs rather than just manifestations of general language ability. They are not independent, however, and their shared relations with general language ability are a likely source of their moderate intercorrelation.

2. Are morphological awareness, syntactic processing, and working memory important predictors of Chinese written composition, and if so, what are the relative magnitudes and independence of their contributions to prediction?— Based on (a) their role in predicting English reading and to a lesser degree, English writing, (b) relations between reading and writing, and (c) characteristics of the Chinese writing system that place a premium on these three constructs, a theoretical rationale exists for expecting morphological awareness, syntactic processing, and working memory to be important predictors of Chinese written composition. However, there is scant empirical evidence that tests this proposition. Results from the present study supported the importance of morphological awareness, syntactic processing, and working memory as important predictors of Chinese written composition. Factor correlations between the predictors of morphological awareness, syntactic processing, and working memory and the criterion of written composition obtained from the confirmatory factor analyses, which are equivalent to bivariate regression coefficients, ranged from .6 to .8.

Finding morphological awareness to be an important predictor of Chinese written composition is consistent with previous studies that suggest it is related to learning to read in Chinese (Hao et al., 2013; Kuo & Andersno, 2006; Liu & McBride-Chang, 2010; Packard et al., 2006; Shu et al., 2006; Zhang et al., 2012) and predicts Chinese writing ability (Leong & Ho, 2008; Leong et al., 2013). Finding working memory to be an important predictor of Chinese written composition is consistent with results of previous research that has focused primarily on working memory in monolingual Chinese- and English-speaking children (Chung & McBride-Chang, 2011; Kellogg, 2001, 2004). Working memory may contribute to writing performance because of the need to hold information in short-term working memory while retrieving information from long-term memory (McCutchen, 2011; Vanderberg & Swanson, 2007). During this process, mental representation and focused manipulation of information are important. The role of syntactic processing appeared to be larger for higher relative to lower grades. This is consistent with the observation that more skilled writers apply their knowledge of syntax to their writing to a greater extent than do less skilled writers (Cromer & Wiener, 1966), and also with the observation that knowledge of syntactic structures is necessary for processing higher-level genres (Beers & Nagy, 2009, 2011).

Turning to relative magnitudes of prediction, the results of dominance analysis indicated that working memory was the strongest predictor of Chinese writing, followed by morphological awareness and syntactic processing which were largely comparable with some trend for morphological awareness to dominate syntactic processing as a predictor. These results are comparable with research showing the importance of working memory as a predictor of writing in English (Berninger et al., 2002; Fitzgerald & Shanahan, 2000; Graham, 2006; Shanahan, 2006).

Finally, we wanted to determine whether morphological awareness, syntactic processing, and working memory made independent contributions to prediction of Chinese written expression or whether their predictive relations were redundant, perhaps because they were correlated with language ability and language ability in turn predicted writing. The results of structural equation modeling supported the independence of their contribution to prediction.

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Significant structure coefficients were found for each predictor when they were included as simultaneous predictors of written composition (Table 6) without including text processing as a mediator.

3. Are observed predictive relations mediated by text comprehension?—Given the similarities and differences between reading and writing discussed earlier, it was important to determine whether predictive relations between the three key constructs of morphological awareness, syntactic processing, and working memory and the dependent variable of Chinese written composition might be mediated by text comprehension. We therefore compared alternative models that proposed that predictive relations between morphological awareness, syntactic processing, and working memory were (a) unmediated, (b) partially mediated, or (c) fully mediated by text comprehension.

Our results were consistent with the view that the predictive role of morphological awareness, syntactic processing, and working memory in accounting for individual differences in written composition is mediated through text comprehension. The mediation model accounted for approximately 75 percent of the variance in written composition. The results supported full rather than partial mediation, and are consistent with other studies that suggest writing depends on reading (Ahmed et al., in press; Fitzgerald & Shanahan, 2000; Shanahan & Lomax, 1986). However, further research in necessary to support text comprehension as a true mediator. At a minimum, our results indicate that morphological awareness, syntactic processing, and working memory do not predict written composition independently of text comprehension. A true mediating role would require evidence that text comprehension actually facilitates written composition. Without further evidence from longitudinal and experimental studies, it is possible that the observed relation between text comprehension and written composition might be subserved by a third construct such as language or verbal aptitude.

It should also be noted that in the design of the study we asked our participants to write three different genres of composition– narration, argumentation and exposition – so as to provide as comprehensive a picture as possible of the students' writing performance. Even though our intent was not to analyze the effects of our predictors on each kind of writing, we were also interested in the relative performance of the students. The results show the general trend of better performance of narratives, then expository writing followed by argumentation writing, grade for grade (Table 1). This differential performance by the Grades 4, 5 and 6 students is in keeping with the findings of the literature (Bereiter & Scardamalia, 1987; Langer, 1986). There is also evidence from recent reading psychology literature that different competencies contribute to children's comprehension of narrative, expository and argumentive texts because of their different structure and different demands made on resource allocation (Best, Floyd, & McNamara, 2008; Reznitskaya et al., 2007). It is likely what is known for reading applies equally for writing (Englert, Stewart, & Hiebert, 1988).

For our specially designed text comprehension tasks with 4 narrative and 4 expository texts and the use of open-ended written comprehension tasks emphasizing inferencing, we also aimed at a broader portrayal of text comprehension. Our approach in designing the text comprehension tasks should address some of the concerns raised about the influence of text and question types influencing reading comprehension (Eason, Goldberg, Young, Geist, & Cutting, 2012). What is not known is the mediating effect of particular genres of text on particular genres of writing. What is also not known is the effect of prior knowledge and knowledge utilization in writing. From inspection of the writing protocols and observation of the students it seemed that they were more intent on content generation and followed the task-execution model of knowledge telling rather than the knowledge transformation of Bereiter and Scadamalia (1987).

The existing literature has not yet settled on a clear consensus about the nature and direction of relations between reading and writing (Aarnoutse, van Leeuwe & Verhoeven, 2005; Abbott et al., 2010; Babayiğit & Stainthorp, 2011; Berninger, Vaughan. et al., 2002; Caravolas, Hulme & Snowling, 2001; Cataldo & Ellis, 1988; Lerkkanen, Rasku-Puttonen, Aunola & Nurmi, 2004; Shanahan & Lomax, 1986; Sprenger-Charolles, Siegel, Bechennec & Serniclaes, 2003). Text comprehension and written composition would seem to draw on similar linguistic and cognitive mechanisms and are likely to be mutually facilitative, but further studies are needed to understand their co-development.

4. Developmental differences or invariance?—In the present study, we analyzed the data separately by grade to examine the extent to which our results varied by grade across the developmental range represented by fourth through sixth grades. The results supported developmental invariance on two levels. First, the measurement models were largely invariant across the three grades, supporting the assertion that the latent variables used to represent the constructs of interest were equivalent across the three grades. This enabled examination of changed in latent variable means across grades. Second, relations among the latent variables also were largely invariant across grades. These results indicate that the fourth through sixth grade students differed primarily in latent variable means, rather than in what the latent variables measured or how they were related with one another. These results are consistent with other recent studies that showed evidence of developmental invariance in writing (Guan et al., 2013; Wagner et al., 2011), although it is important to keep in mind the relatively limited developmental range represented by the fourth through sixth grades.

Limitations, Implications and Future Directions

One limitation of our study is relying on a cross-sectional rather than a longitudinal design. Although this design has the virtue of a relatively larger number of participants and a shorter duration compared to a longitudinal design, examination of developmental differences is confounded with potential cohort effects. A longitudinal design would be particularly helpful for a more rigorous test of mediational relations (Abbott, Amtmann, & Munson, 2006). A second limitation is the limited developmental range represented by including participants from grades four through six. Although writing performance does change over this period of time, a larger developmental range would be helpful in studying what changes and what does not with development. A third limitation is the limited nature of our writing tasks. The methods for scoring quality of writing and comprehension were not typical and that for the quality scores some of the reliabilities were less than might be desired. Also, we did not incorporate important topics such as the processes involved in planning, formulating ideas, editing, and revising them to form coherent and cohesive written texts; writing for different purposes; and discourse knowledge about forms of writing (Graham, 2006; Graham & Harris, 2007; Graham & Perin, 2007; Olinghouse & Graham, 2009). Our writing tasks were group administered, which makes it possible that the writing behavior of a given student was influenced by the surrounding context of other students. Further, we did not control for the effect due to legibility before we scored the students' writing task (Graham, Harris, & Hebert, 2011). A meta-analysis by these authors suggests that legibility has a large effect on scoring quality of writing (Graham, & Hebert, 2011). Another limitation is that all students were from a single school, although this might assure participants coming from similar SES background and language/literacy experience. We also acknowledge that our results apply to normally developing writers and may not apply to students with impairments in writing or other aspects of language.

Despite its limitations, the current study provides greater contributions and practical implications to the field of educational psychology, educational practice, and possibly educational policy. First, the study might be one of the first that established the important measureable predictors for Chinese written composition. Second, by conducting dominance analysis, the study might be one of the first that revealed the relative magnitudes and independent contributions of each unique linguistic and cognitive factor to written composition. In writing practices, the teachers will be informed of how to focus on their elements of writing instructions to improve students' writing performance. The third contribution is to theories of educational psychology of writing research. The study conducted confirmatory factor analysis to distinguish our three-factor model of writing (morphological awareness, syntactic processing and working memory) from the single factor model of general language ability. Fourth, we compared theoretically the alternative models of unmediation, partial mediation, and full mediation of text comprehension of these three key constructs and Chinese written composition. As well, we provided theoretically based empirical evidence to show that the predictive relations between the three key constructs of linguistic and cognitive factors and the dependent variable of Chinese written composition might be mediated by text comprehension. This provides a potential alternative view of how we could address the predictive relations among reading and writing variables. Our fifth contribution is to educational policy. This relates to ways of assessing reading and writing, and the predictive relations between linguistic and cognitive measures mediated by text comprehension. The results of our study might suggest a blueprint of reading and writing for educational policy makers.

In future studies, it will be important to consider different genres of written composition more specifically, as they may make different demands on planning, translating and review processes and on cognitive resources such as working memory that underlie them (Kellogg, 2001; Torrance & Jeffery, 1999). Finally, there is a need for randomized controlled trials of instructional approaches and interventions directed towards improving writing skill (Cutler & Graham, 2008).

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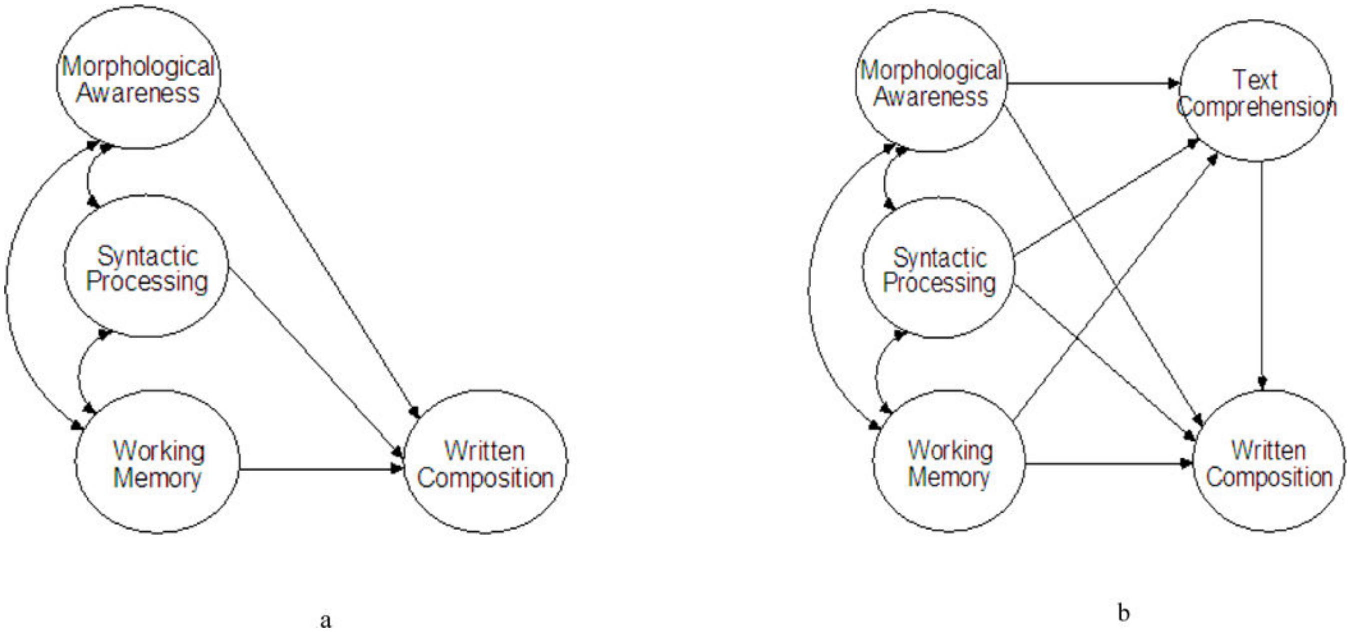

Figure 1.
Proposed Models of Prediction of Written Composition

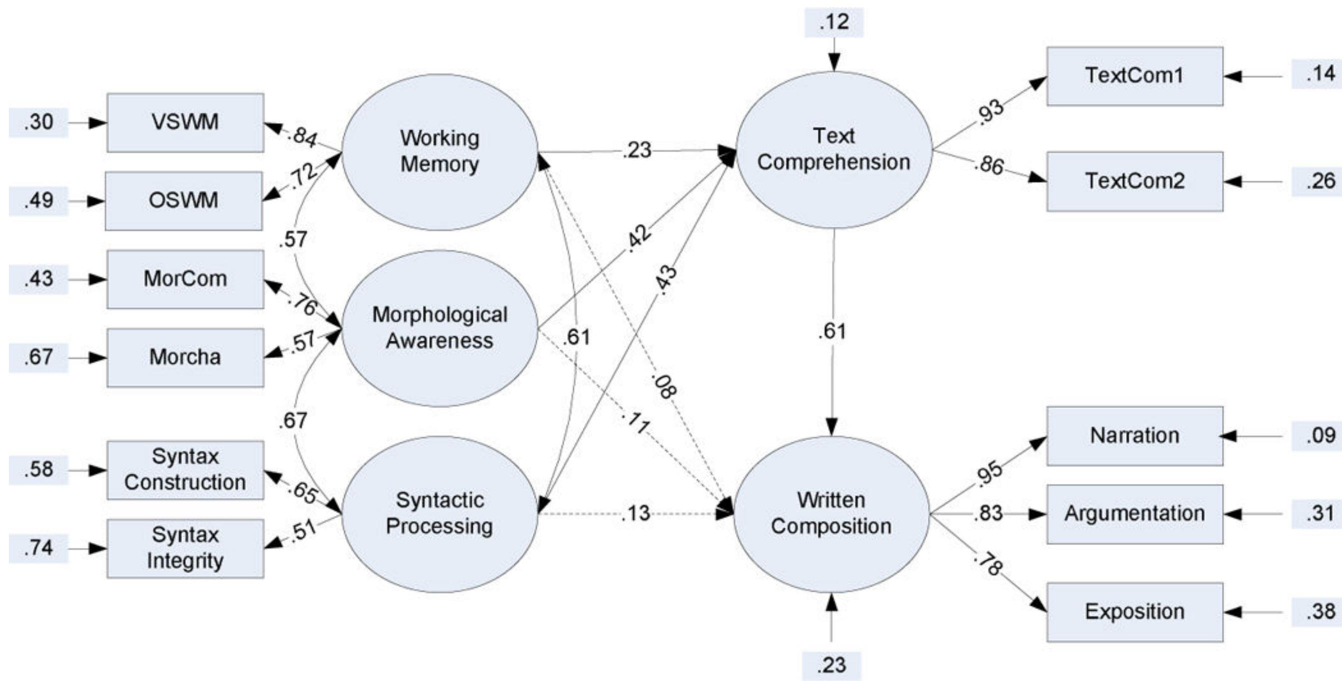

Figure 2.

Structural equation model of Grade 4 showing standardized effects of working memory, morphological awareness, syntactic processing on text comprehension and written composition. VSWM = verbal span working memory, OSWM = operation span working memory, MorCom = morphological compounding (from Leong & Ho, 2008), MorCha = morphological chain. All factor loadings, correlation coefficient, regression coefficients, residual variances are significant at $p < .03$ except those in dashed line ($ps > .37$).

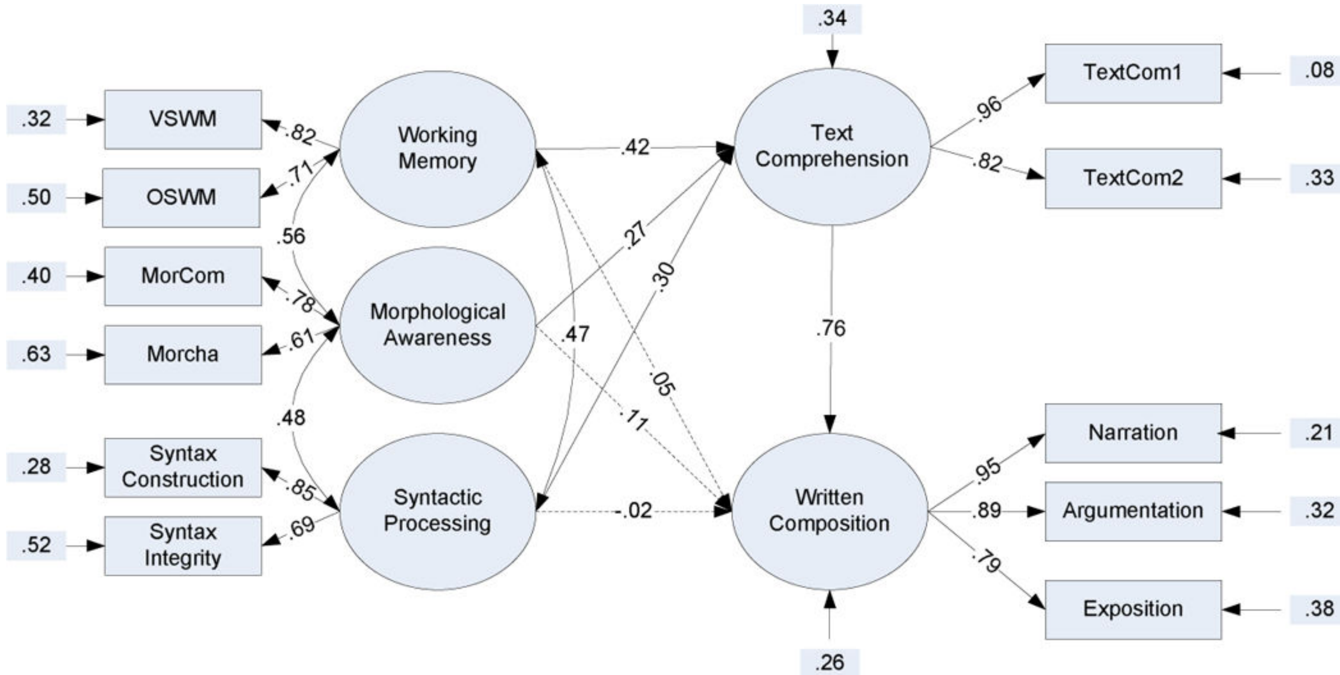

Figure 3.

Structural equation model of Grade 5 showing standardized effects of working memory, morphological awareness, syntactic processing on text comprehension and written composition. VSWM = verbal span working memory, OSWM = operation span working memory, MorCom = morphological compounding (from Leong & Ho, 2008), MorCha = morphological chain. All factor loadings, correlation coefficient, regression coefficients, residual variances are significant at $p < .01$ except those in dashed line ($ps > .15$).

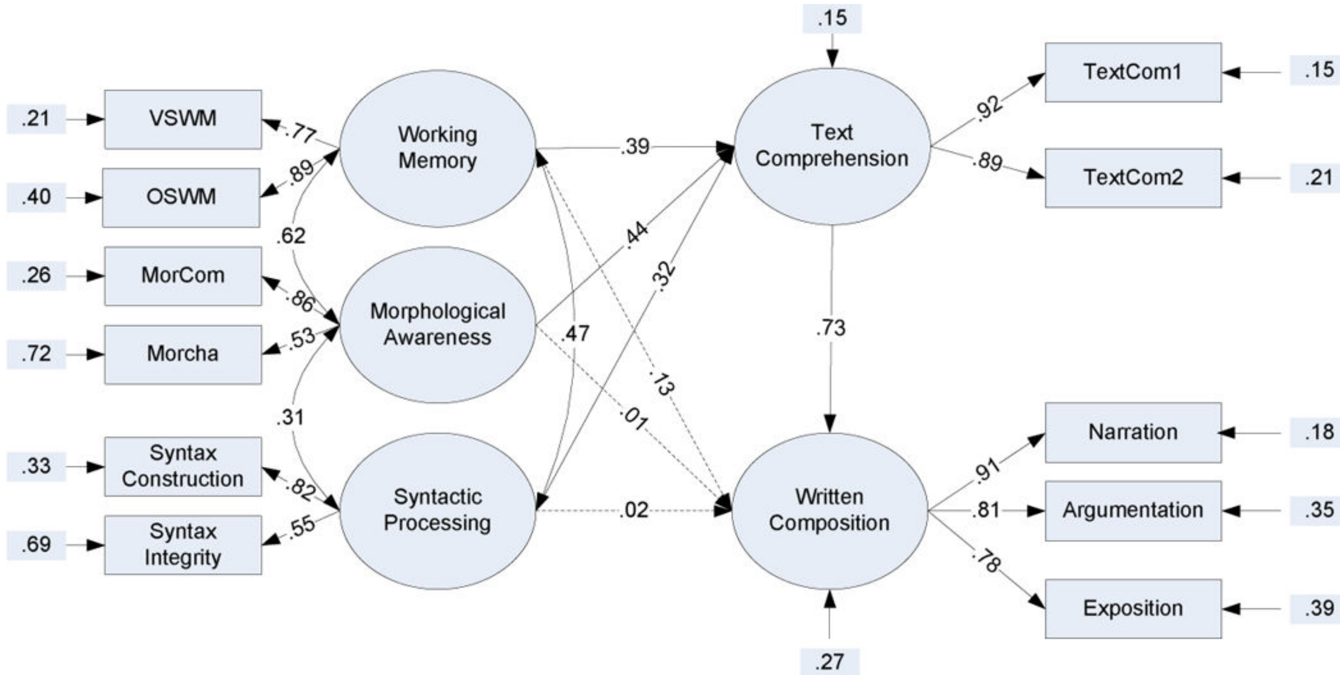

Figure 4.

Structural equation model of Grade 6 showing standardized effects of working memory, morphological awareness, syntactic processing on text comprehension and written composition. VSWM = verbal span working memory, OSWM = operation span working memory, MorCom = morphological compounding (from Leong & Ho, 2008), MorCha = morphological chain. All factor loadings, correlation coefficient, regression coefficients, residual variances are significant at $p < .002$ except those in dashed line ($p > .28$).

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Table 1

Descriptive Statistics of All Tasks by Grade

Task	M	SD	Skewness	Kurtosis	Shapiro-Wilk	*p*-value
Grade 4 (n=246)						
Verbal Span Working Memory	15.09	6.94	−0.25	−1.30	0.92	.000
Operational Span Working Memory	16.30	5.13	−1.28	0.70	0.82	.000
Morphological Compounding	10.05	3.60	0.47	−0.05	0.97	.000
Morphological Chain	10.09	4.92	0.43	−0.79	0.95	.000
Syntax Construction	11.38	3.63	−0.26	−0.76	0.97	.000
Syntax Integrity	11.50	3.71	0.15	−0.48	0.98	.003
Text Comprehension Task 1	14.29	6.84	0.77	0.65	0.95	.000
Text Comprehension Task 2	14.43	5.61	0.24	−0.54	0.98	.004
Narrative Writing	52.09	9.42	−0.69	0.53	0.92	.000
Argumentation Writing	47.49	11.27	−0.11	−1.44	0.98	.000
Expository Writing	51.92	9.63	−0.80	0.60	0.90	.000
Grade 5 (n=242)						
Verbal Span Working Memory	17.55	5.68	−0.91	−0.41	0.91	.000
Operational Span Working Memory	17.04	4.27	−1.78	3.16	0.80	.000
Morphological Compounding	12.35	4.30	−0.12	0.07	0.98	.008
Morphological Chain	12.82	5.39	0.18	−0.54	0.98	.001
Syntax Construction	13.74	3.62	−0.71	1.53	0.95	.000
Syntax Integrity	12.96	3.42	−0.70	0.65	0.96	.000
Text Comprehension Task 1	19.00	7.69	−0.28	−1.11	0.94	.000
Text Comprehension Task 2	19.24	7.32	−0.28	−0.86	0.97	.000
Narrative Writing	60.65	9.33	−0.37	−0.38	0.96	.000
Argumentation Writing	56.92	13.54	−0.32	−0.63	0.97	.000
Expository Writing	62.69	10.60	−1.33	1.66	0.86	.000
Grade 6 (n=261)						
Verbal Span Working Memory	19.31	5.38	−1.05	−0.35	0.83	.000
Operational Span Working Memory	18.83	3.74	−1.92	2.79	0.64	.000
Morphological Compounding	14.09	4.16	0.24	0.75	0.98	.004

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Task	**M**	**SD**	**Skewness**	**Kurtosis**	**Shapiro-Wilk**	***p*-value**
Morphological Chain	14.25	6.61	0.06	−1.18	0.95	.000
Syntax Construction	15.44	2.48	−1.36	3.00	0.90	.000
Syntax Integrity	14.44	3.12	−0.88	1.21	0.94	.000
Text Comprehension Task 1	21.25	7.72	0.03	−0.89	0.97	.000
Text Comprehension Task 2	21.83	6.96	−0.40	−0.52	0.97	.000
Narrative Writing	75.73	13.99	−1.36	1.59	0.86	.000
Argumentation Writing	67.26	14.40	−0.85	0.42	0.94	.000
Expository Writing	70.78	12.92	−1.29	1.88	0.89	.000

Table 2

Correlations of Tasks for Grades 4, 5, and 6

Variable	1	2	3	4	5	6	7	8	9	10	11
Grade 4 (n=246)											
1. Verbal Span Working Memory	–										
2. Operational Span Working Memory	.59	–									
3. Morphological Compounding	.41	.29	–								
4. Morphological Chain	.22	.19	.44	–							
5. Syntax Construction	.30	.27	.29	.28	–						
6. Syntax Integrity	.32	.23	.24	.29	.34	–					
7. Text Comprehension Task 1	.56	.44	.55	.45	.50	.41	–				
8. Text Comprehension Task 2	.60	.43	.61	.41	.45	.42	.79	–			
9. Narrative Writing	.49	.51	.53	.44	.50	.38	.82	.64	–		
10. Argumentation Writing	.48	.46	.51	.39	.43	.33	.72	.62	.79	–	
11. Expository Writing	.41	.48	.39	.34	.30	.22	.59	.44	.74	.66	–
Grade 5 (n=242)											
1. Verbal Span Working Memory	–										
2. Operational Span Working Memory	.59	–									
3. Morphological Compounding	.34	.37	–								
4. Morphological Chain	.22	.30	.47	–							
5. Syntax Construction	.34	.30	.28	.25	–						
6. Syntax Integrity	.24	.23	.28	.31	.58	–					
7. Text Comprehension Task 1	.55	.49	.50	.34	.51	.37	–				
8. Text Comprehension Task 2	.50	.47	.43	.32	.52	.38	.78	–			
9. Narrative Writing	.45	.40	.42	.39	.35	.23	.78	.61	–		
10. Argumentation Writing	.40	.35	.32	.27	.42	.35	.64	.48	.73	–	
11. Expository Writing	.47	.46	.44	.37	.46	.37	.64	.47	.69	.69	–
Grade 6 (n=261)											
1. Verbal Span Working Memory	–										
2. Operational Span Working Memory	.68	–									
3. Morphological Compounding	.45	.38	–								

Variable	1	2	3	4	5	6	7	8	9	10	11
4. Morphological Chain	.43	.37	.45	–							
5. Syntax Construction	.28	.32	.18	*.12*	–						
6. Syntax Integrity	.31	.33	.25	.17	.48	–					
7. Text Comprehension Task 1	.65	.54	.65	.38	.39	.37	–				
8. Text Comprehension Task 2	.66	.57	.55	.29	.51	.45	.82	–			
9. Narrative Writing	.57	.50	.51	.35	.40	.35	.69	.67	–		
10. Argumentation Writing	.58	.52	.44	.29	.33	.35	.68	.66	.72	–	
11. Expository Writing	.47	.42	.45	.22	.27	.28	.58	.59	.74	.62	–

Note. All coefficients are statistically significant at the .05 level except the ones in bold.

Table 3

Standardized Factor Loading (standard error) and Inter-factor Correlations from Confirmatory factor Analysis

Task	Grade 4					Grade 5					Grade 6				
	WM	MP	SP	TC	WC	WM	MP	SP	TC	WC	WM	MP	SP	TC	WC
Verbal Span Working Memory	.84 (.05)					.79 (.04)					.89 (.03)				
Operational Span Working Memory	.71 (.06)					.74 (.05)					.77 (.04)				
Morphological Compounding		.75 (.05)					.79 (.06)					.87 (.07)			
Morphological Chain		.58 (.05)					.60 (.06)					.51 (.06)			
Syntax Construction			.64 (.07)					.87 (.05)					.74 (.06)		
Syntax Integrity			.53 (.06)					.67 (.06)					.65 (.07)		
Reading Comprehension Task 1				.92 (.02)					.95 (02)					.91 (.02)	
Reading Comprehension Task 2				.87 (.02)					.83 (.03)					.90 (.02)	
Narrative Writing					.94 (.02)					.84 (.03)					.90 (.03)
Argumentation Writing					.85 (.03)					.83 (.03)					.82 (.02)
Expository Writing					.76 (.04)					.84 (.03)					.79 (.05)
Inter-factor Correlations															
Morphological Awareness	.57	–				.58	–				.61	–			
Syntactic Processing	.61	.67	–			.47	.46	–			.51	.35	–		
Text Comprehension	.74	.84	.84	–		.72	.62	.68	–		.81	.76	.68	–	
Written Composition	.69	.78	.79	.85	–	.66	.62	.57	.77	–	.73	.65	.57	.85	–

Note. All coefficients are significant at $p < .001$.

Table 4

Examination of measurement invariance between Grades 4, 5, and 6

		df	χ^2	CFI	TLI	RMSEA(90% CI)	SRMR	Δdf	$\Delta\chi^2$
Model 1	Baseline Model	102	283.23***	.96	.93	.08 (.07, .09)	.04		
Model 2 (compared to Model 1)	Model with equal loadings	114	321.78***	.95	.93	.08 (.07, .09)	.06	12	37.90***
Model 3 (compared to Model 1)	Model with equal loadings except narrative writing of Grade 5	113	294.55***	.96	.93	.08 (.07, .09)	.05	11	14.03
Model 4 (compared to Model 3)	Model 3 + equal intercepts	125	329.59***	.95	.93	.08 (.07, .09)	.05	12	34.90***
Model 5 (compared to Model 3)	Model 3 + equal intercepts except operational span working memory of Grade 5 and text comprehension task 2 of Grades 5 and 6	122	299.95***	.96	.94	.07 (.06, .09)	.05	9	14.61

Note.

*** $p<.001$. CFI = Comparative Fit Index; TLI = Tucker Lewis coefficient; RMSEA = root mean square error of approximation; SRMR=standardized root mean squared residual;

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Table 5

Latent means, variances, and latent standardized effect sizes

	Grade 4		Grade 5		Grade 6		Standardized Effect Size		
	Mean	**Variance**	**Mean**	**Variance**	**Mean**	**Variance**	**Grade5−Grade4**	**Grade6−Grade5**	**Grade6−Grade4**
Working Memory	0.00	32.33	2.43	20.48	4.06	21.63	0.47	0.36	0.78
Morphological Awareness	0.00	7.59	2.33	10.10	4.09	11.95	0.78	0.53	1.30
Syntactic Processing	0.00	5.37	1.99	7.12	3.87	3.94	0.80	0.80	1.80
Text Comprehension	0.00	37.05	4.67	51.33	6.75	51.05	0.70	0.29	1.01
Written Composition	0.00	194.70	9.74	229.76	19.41	176.18	0.67	0.68	1.43

Table 6

Bivariate Correlations, structure coefficients, structure coefficients with mediation, and indirect effects for grades 4, 5, and 6.

Grade	Variable	Correlation	Structure Coefficient	Structure coefficient with mediator	Indirect effect	
					Estimate	Bootstrap 95% CI
Grade 4						
	Working Memory	$.69^{***}$	1.02^{*}	0.31	0.57	(−0.25, 3.46)
	Morphological Awareness	$.78^{***}$	1.96^{**}	0.57	1.29	(−0.99, 5.77)
	Syntactic Processing	$.79^{***}$	2.58^{*}	0.79	1.59	(−0.17, 14.77)
Grade 5						
	Working Memory	$.66^{***}$	1.91^{**}	0.24	1.70	(0.82, .3.28)
	Morphological Awareness	$.62^{***}$	1.48^{**}	0.53	0.95	(0.34, 2.08)
	Syntactic Processing	$.57^{***}$	1.73^{**}	0.09	1.28	(0.56, 2.38)
Grade 6						
	Working Memory	$.73^{***}$	1.62^{**}	0.59	1.32	(0.06, 2.75)
	Morphological Awareness	$.65^{***}$	1.51^{**}	0.04	1.22	(0.04, 3.55)
	Syntactic Processing	$.57^{***}$	2.01^{*}	0.12	1.53	(0.22, 5.32)

Note.

* $p<.01$;

** $p<.01$;

*** $p<.001$.

Table 7

Examination of equality of path coefficients between Grades 4, 5, and 6

		df	χ^2	Δdf	$\Delta\chi^2$
Model 1	Baseline Model	122	334.22***		
Model 2 (compared to Model 1)	Model with equal WM→TC	124	342.11***	2	7.43*
Model 3 (compared to Model 1)	Model with equal MP→TC	124	334.13***	2	1.37
Model 4 (compared to Model 1)	Model with equal SP→TC	124	330.70***	2	0.85
Model 5 (compared to Model 1)	Model with equal TC→Writing	124	334.24***	2	0.60
Model 6 (compared to Model 1)	Model with equal WM→Writing	124	332.88***	2	0.45
Model 7 (compared to Model 1)	Model with equal MP→Writing	124	335.54***	2	1.32
Model 8 (compared to Model 1)	Model with equal SP→Writing	124	335.22***	2	0.99

Note.

* p<.05

** p<.01

*** p<.001.

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Table 8

Dominance Analysis Results of Variables Predicting Writing

	Unique contribution of predictors to writing											
	Grade 4				Grade 5				Grade 6			
Subset model	**R^2**	**WM**	**MP**	**SP**	**R^2**	**WM**	**MP**	**SP**	**R^2**	**WM**	**MP**	**SP**
Models with one predictor												
WM	.34	.	.14	.08	.28	.	.08	.09	.39	.	.04	.04
MP	.32	.16	.	.08	.23	.13	.	.09	.24	.19	.	.10
SP	.24	.18	.17	.	.21	.15	.11	.	.18	.24	.15	.
Models with two predictors												
WM-MP	.48	.	.	.03	.36	.	.	.05	.42	.	.	.04
WM-SP	.42	.	.09	.	.37	.	.05	.	.43	.	.03	.
MP-SP	.40	.11	.	.	.32	.09	.	.	.34	.12	.	.
Models with three predictors												
WM-MP-SP	.52	.	.	.	.42	.	.	.	.46	.	.	.

Table 9

The Sample Dominance and Their Means, Standard Errors, Probabilities and Reproducibility over 1000 Bootstrap Samples

	i	j	D_{ij}	$\overline{D}_{ij}$	$SE(D_{ij})$	P_{ij}	P_{ji}	P_{noij}	reproducibility
Grade 4	1	2	1.0	0.62	0.46	0.56	0.32	0.11	0.56
	1	3	1.0	0.95	0.19	0.92	0.02	0.06	0.92
	2	3	1.0	0.93	0.22	0.90	0.04	0.07	0.90
Grade 5	1	2	1.0	0.84	0.35	0.82	0.14	0.05	0.82
	1	3	1.0	0.85	0.34	0.83	0.13	0.04	0.83
	2	3	0.5	0.53	0.45	0.43	0.38	0.19	0.19
Grade 6	1	2	1.0	0.99	0.09	0.98	0.00	0.02	0.98
	1	3	1.0	0.96	0.15	0.93	0.01	0.06	0.93
	2	3	0.5	0.60	0.41	0.45	0.25	0.31	0.31

Note. X1 = Working Memory; X2 = Morphological Processing; X3 = Syntactic Processing