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Predicting Levels of Reading and Writing Achievement in Typically Developing, English-Speaking 2nd and 5th Graders

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Abstract

Human traits tend to fall along normal distributions. The aim of this research was to evaluate an evidence-based conceptual framework for predicting expected individual differences in reading and writing achievement outcomes for typically developing readers and writers in early and middle childhood from Verbal Reasoning with or without Working Memory Components (phonological, orthographic, and morphological word storage and processing units, phonological and orthographic loops, and rapid switching attention for cross-code integration). Verbal Reasoning (reconceptualized as Bidirectional Cognitive-Linguistic Translation) plus the Working Memory Components (reconceptualized as a language learning system) accounted for more variance than Verbal Reasoning alone, except for handwriting for which Working Memory Components alone were better predictors. Which predictors explained unique variance varied within and across reading (oral real word and pseudoword accuracy and rate, reading comprehension) and writing (handwriting, spelling, composing) skills and grade levels (second and fifth) in this longitudinal study. Educational applications are illustrated and theoretical and practical significance discussed.

Keywords

Predicting Reading Achievement; Predicting Writing Achievement; Verbal Reasoning; Bidirectional Cognitive-Language Translation; Verbal Working Memory; Language Learning Mechanism

Research across different countries and languages is validating effective ways to teach *reading* (e.g., Adams, Foorman, Lundberg, & Beeler, 2012; Beck & McKeown, 2001; Cain & Oakhill, 2007; Denton, Vaughn, Wexler, Bryan, & Reed, 2012; Stahl, & Nagy, 2005),

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writing (e.g., Arfé, Dockrell, Berninger, in press; Graham, MacArthur, & Fitzgerald, 2007; Limpo, & Alves, 2013; Rijlaarsdam, van den Bergh, & Couzijn, 2004; Troia, 2009), and *writing-reading integration* (e.g., Berninger & Abbott, 2010; Graham, and Hebert, 2010; Shanahan, 2006), for different age levels, and both typical language learners and those with specific learning disabilities. However, the issue of when a learner has reached an acceptable level of achievement in reading or writing remains unresolved. The challenge in doing so is that variation in levels of reading and writing achievement is normal in typically developing readers and writers as well as those with specific learning disabilities (for review of evidence, see Berninger, 2009). That is why normed tests of specific reading and writing skills have been developed to assess variation in levels of achievement on a specific skill in a specific age group or at a specific grade level. Scores on normed tests fall along a continuous distribution and it is impossible for all students of a certain age or grade to be at exactly the same level of achievement.

Given this normal variation and scores on normed tests falling along a continuous distribution, little is known about how to predict a level of expected achievement in response to instruction (RTI), both for typically developing readers and writers and those with specific learning disabilities. Twin studies across countries have demonstrated that such variations in reading and spelling are influenced by both genetics (inherited traits) and environmental variables (e.g., Byrne et al., 2008; Friend & Olson, 2008; Olson, Byrne, & Samuelson 2009). One way to sort out the role of genetics in reading and writing achievement is to validate behavioral markers of associated genetic mechanisms. Individually administered measures of such behavioral markers of genetic mechanisms are called phenotypes. Considerable research has validated such phenotypes (e.g., Grigorenko et al., 1997; Plomin, DeFries, McClearn, & McGuffin, 2008; Raskind, Peters, Richards, Eckert, & Berninger, 2012; Schulte-Korne et al., 1998; Wijsman et al., 2000).

Grade-appropriate, evidence-based instructional practices may help students read and write at their current grade level, but may not fully eliminate genetic vulnerability at later grades when curriculum requirements change. Genetic influences on written language learning may still be observed (e.g., Samuelsson et al., 2008); these are thought to (a) be heterogeneous for reading and writing skills (Raskind et al., 2012), and (b) affect different aspects of brain development, ranging from neural migration shortly after conception, to myelination, to protein production resulting from mRNA transcription and translation processes (see Batshaw, Roizen, & Lotrecchiano, 2013). Thus, even though a student might respond to instruction (RTI) at the behavioral level at a particular time in schooling, with resultant epi-genetic effects (see Cassidy, 2009), the remaining genetic vulnerability in DNA sequencing may surface again and continue to affect RTI as the nature of curriculum and academic requirements change across schooling.

Thus, the purpose of the current research was to investigate two kinds of individually administered measures that might be used as predictors of a reasonable level of achievement in specific reading and writing skills in a sample of typically developing language learners who exhibit normal variation. One predictor used was verbal reasoning, for which there is prior evidence that it is related to reading and writing achievement (e.g., Greenblatt, Mattis, & Trad, 1990; Prifitera, Weiss, Saklofske, & Rolfhus, 2005; and Vellutino, Scanlon &

Tanzman, 1991). The second set of predictors was evidence-based phenotypes for verbal working memory components supporting language learning, for which there is prior evidence that they are related to reading and writing achievement (e.g., for review, see Berninger et al., 2006; Berninger & Richards, 2010). The amount of variance explained in specific reading and writing outcomes was examined at two grade levels representative of early childhood (second grade) and middle childhood (fifth grade). The rationale for the predictors used at each of these representative grade levels is explained in the sections that follow.

Predictors

Verbal reasoning

Early in the 20th century the French government passed a law requiring all French children to attend school and commissioned Binet and his colleague Simon to develop measures that would identify those who might learn more quickly and need to progress more quickly as well as those who might learn more slowly and need specialized assistance (Myers, 2004). The use of these assessment measures spread to the United States, where they were developed further (Binet & Simon, 1916). Although those who developed these assessment instruments never thought a single score could address this issue of identifying individual differences in rate of learning (Meyers, 2004), the use of a single score referred to as IQ for Intelligent Quotient became common educational practice. In the United States these scores were used to establish expected level of achievement for purposes of placement in programs for gifted education or special education (intellectual disabilities or specific learning disabilities).

However, research has not supported the use of IQ-achievement discrepancy for identification of specific learning disabilities (e.g., Francis, Fletcher, Stuebing, Lyon, Shaywitz, & Shaywitz, 2005). To begin with, although originally the single score was a quotient based on measured intellectual age compared to chronological age, test developers developed standard scores that could be compared across ages in reference to the normal bell shaped curve and abandoned use of quotients. Thus, the term IQ is not accurate and should not be used. Even though raw scores improve with age, relative performance on standard scores compared to age peers may stay the same, decline, or improve across age. Moreover, no single amount of discrepancy has ever been found that differentiates those who do and do not have specific learning disabilities; at most full scale scores may be used to differentiate those who are and are not developing in the typical range (e.g., Silliman & Berninger, 2011). Finally, a number of studies employing factor analyses identified reliable factors within the widely used Wechsler Scales—Verbal Comprehension[1], Perceptual Organization, Working Memory, and Processing Speed--in the most recent 4th Edition. Thus, the publishers of the Wechsler Scales, 4th Edition recommend use of the Index scores for these factors rather than the full scale score (see Prifitera, Weiss, Saklofske, & Rolfhus, 2005). Of the four index scores, the one now referred to as Verbal Comprehension was found to be the best predictor of reading achievement in both referred (e.g., Greenblatt,

[1]The WISC 4 Verbal Comprehension Scale measures the same construct referred to as verbal reasoning in the research on the most predictive cognitive measures for academic achievement.

Mattis, & Trad, 1990) and unreferred (Vellutino, Scanlon & Tanzman, 1991) samples. A cut-off criterion set at the border between average and low average range was found in one multi-generational family genetics study to be effective in differentiating learning problems in those with dyslexia (Verbal Comprehension Factor at or above standard score of 90 or the 25th %tile) and learning problems due to other neurogenetic disorders such as Fragile X) (e.g., Raskind et al., 2005).

Thus, the Verbal Comprehension Index on the Wechsler Scale was used as a predictor in the current study, which focused on written language learning. However, it is not clear whether this Index Score is purely cognitive, as subtest measures on the Wechsler Scale are assumed to be, or purely Verbal, that is, language-based, as implied by their name. As explained by Stahl and Nagy (2005), semantics or word meaning does not belong solely to the language or cognitive domain. Vocabulary involves the complex, seldom one-to-one relationships between the concepts to which words point and the use of words to express the concept. For example, the same spoken or written word can have multiple meanings, which sometimes can be referenced with a one word synonym but often require use of multiple words to explain precisely one of the meanings, as listed in unabridged dictionaries. For further discussion of this reconceptualization, which suggests that what is really being measured is the cognitive ← → linguistic translation process that can occur at any of multiple levels of language ranging from words to multi-word clausal or idiomatic constructions or text structures, see Berninger, Rijlaarsdam, & Fayol (2012).

Indeed a task analysis of each subtest contributing to the Verbal Comprehension Index suggests that something different from pure reasoning with language is being assessed. For similarities, the child has to translate concepts underlying named words into a word or phrase expressed in oral language. For vocabulary, the child has to explain the meaning of a named word by choosing words and constructing phrases and/or syntax expressed in oral language. For verbal comprehension, the child has to answer a question that requires both accessing knowledge of the real world and expressing that knowledge in words, phrases, and syntax expressed in oral language. None of these tasks require solving problems with or about language. Rather, this ability to express concepts in the cognitive domain with different levels or units of language may predict level of achievement in specific reading or writing skills, which also draw on the cognitive ← → linguistic translation process.

Working memory components supporting verbal learning

Research has also shown that working memory is necessary to support learning to read and write in typically developing language learners (e.g., Swanson, 1992; Swanson & Berninger, 1995, 1996a, 1996b). However, research does not support the practice of assessing working memory that supports language learning based on a single measure (Swanson, 1996). Decades of research had led to refinement of the concept of working memory, which has evolved (Baddeley, 2002, 2003). Converging evidence supports a multi-component system: (a) storage and processing units for word forms and syntax[2], (b) phonological loop for integrating internal codes with output systems through mouth and orthographic loop for

[2]In the cognitive psychology and working memory research literature, coding refers to both storage and processing of words and other larger units of language (e.g., accumulating words in sentence syntax or text).

integrating internal codes with output systems through the hand, and (c) supervisory attention that regulates working memory processes (for review, see Berninger & Richards, 2010).

Note that storage and processing are defining characteristics of working memory (e.g., Daneman & Carpenter, 1983; Swanson, 1999). *Word form* describes the multiple ways words may be stored (coded) and processed. The *phonological word form* codes spoken words while their speech sounds are processed, for example, analyzed for their component phoneme sounds. The *morphological word form* codes both spoken and written words while their parts – bases and affixes that transform meaning and mark grammar—are processed. The *orthographic word form* codes written words while their constituent letters are processed. *Syntactic coding* stores multiple accumulating words in working memory while syntactic structures contribute to constructing the oral sentence. (e.g., for word-order, content and function words, clause structures, grammatical functions etc.) are processed during listening or reading comprehension or are constructed for oral or written expression. Research has shown that throughout early and middle childhood, all three word forms contribute to reading and spelling (Garcia, Abbott, & Berninger, 2010). Syntactic coding becomes increasingly important beginning in fourth grade and thereafter (e.g., Berninger, Abbott et al., 2010; Berninger, Nagy, & Beers, 2011; Swanson & Berninger, 1995, 1996).

Loops are time-sensitive mechanisms for coordinating internal codes and the motor output connected to those internal codes that engage working memory supporting language and thinking processes (Berninger, 2009). The phonological loop, which facilitates cross-code integration during early language learning (Baddeley, Gathercole, & Papagno, 1998), may also guide internal mental vocalizations during word reading after word identification and decoding become automatic. The orthographic loop may also rely on internal mental conversions of spelling, without heard dictated words, as word-specific spellings and letter formation become more automatic. Rapid Automatic Naming (RAN) (for recent review, see Norton & Wolf, 2012), is a measure of time-sensitive phonological loop function, which growth mixture modeling showed also assesses phonological loop function in students who are typically developing readers and writers (Amtmann, Abbott, & Berninger, 2007, 2008). Timed automatic alphabet writing (Rapid Automatic Letter Writing) is a measure of time-sensitive orthographic loop function (for review of evidence, see Berninger, 2009; Berninger & Richards, 2010).

The panel of *supervisory attention functions* supports focusing attention (inhibit what is irrelevant), switching attention (change focus of attention), and sustaining attention (maintain focus over time). Of these, Rapid Automatic Switching Attention (RAS) was shown to be the most consistently significant predictor of reading and writing skills in typically developing readers and writers in a longitudinal study (Altemeier, Abbott, Berninger, 2008; Amtmann et al., 2007, 2008). Thus, RAS was used in the current study to model supervisory attention.

Early Childhood and Middle Childhood Reading and Writing Achievement

Chall (1983) proposed an influential distinction between an early stage of learning to read in the first three grades and a later stage of reading to learn in subsequent grades. Subsequently other models of reading development were proposed which focused on transition from the prereading to early reading stages (Ehri, 1995), or reading during middle childhood or adolescence (e.g., DeFries, Plomin, & Fulker, 1994; Denton et al., 2012). Likewise, the third-to- fourth grade transition has been shown to be critical for writing achievement when the focus changes from learning to write to writing to learn and writing assignments become more complex and challenging (e.g., Berninger, 2009; Troia, 2009). Therefore, for purposes of the current research we evaluated the model for predicting levels of achievement in specific reading or specific writing skills at a representative grade level during early childhood and during middle childhood. We chose second grade for early childhood and fifth grade for middle childhood from an existing sample for which we had the Verbal Reasoning Index and the same phenotype measures for each working memory component as has been validated in phenotype studies in genetics studies cited earlier.

Research Questions Addressed in Current Study

As explained, there is an empirical basis from past research for using both the Verbal Reasoning Index and a set of working memory component phenotypes as predictors for level of achievement in specific reading and writing skills at two contrasting stages of reading and writing development—early childhood and middle childhood. At the same time, there is also a theoretical basis for evaluating whether Verbal Reasoning and a Multi-Component Working Memory Architecture, alone or combined, can predict reading and writing outcomes; each is hypothesized to play a role in supporting language learning. Verbal Reasoning is an indicator of ability of developing language learners to translate thoughts into language and vice versa. The multi-component working memory architecture, managed by a panel of supervisory attention functions, supports storage and processing of words and accumulating words while the learner interacts with the internal mind and external learning environment through loops in learning to read and write. Outcomes thus included different reading and writing skills shown to be important in early and middle childhood for reading, writing, and reading-writing integration (e.g., Abbott, Berninger, & Fayol, 2010). For reading, substantial evidence exists for the importance of phonological decoding of unknown words, typically assessed with accuracy and rate of reading pseudowords (Wagner & Torgesen, 1987), real word reading on a list without context clues (e.g., Stanovich, 1986) for both accuracy and rate (Biemiller, 1977–1978; Lovett, 1987), and reading comprehension (Cutting, Benedict, Broadwater, Burns, & Fan, 2013; Perfetti, 2007). For writing, substantial evidence exists for assessing handwriting, spelling, and composing (for a review, see Berninger, 2009). At issue was whether the predictor skills that explained unique variance in these outcomes might be different in early and middle childhood.

Four specific research questions were addressed. First, how much variance can be explained in each reading or writing skill with only the Verbal Reasoning Index as the predictor and how much variance can be explained by both the Verbal Reasoning Index and each of the components of verbal working memory supporting language learning? Second, which of the predictors uniquely predicted each reading and writing outcome in second grade and in fifth grade? Third, which of the predictors explain unique variance both in early and middle childhood and which explain unique variance at one developmental level but not the other? Fourth, do beta weights based on the best predictors for each reading and writing skill accurately predict observed reading and writing achievement in individual typically developing readers and writers? This last question is relevant to the cutting-edge issue of translation science in education—translating research findings into educational practice (Mayer, 2007).

Method

Participants

This research was approved by the Institutional Review Board. Typically developing readers and writers were recruited from the largest school district in a state in the Northwest of the United States; this district, which is the largest in the state and in the largest city in the state, is located near a research university, has a student population representative of the general population in this Pacific Rim region of the United States, and has among the highest scores on the state mandated test for annual yearly progress on meeting standards despite the diversity of students served. Letters were distributed to all parents of children completing kindergarten in the 91 schools in the school district. Children who were enrolled by their parents in first grade were then tested annually for five years. Because enrolled children were from most of the schools in the district, and if from the same school, different classrooms, and schools attended changed over the course of the study, classroom instruction was not a systematic variable in this sample.

The current study analyzed data for students when they were in second grade (n=128; 57 males, 71 females), and again when they were in fifth grade (n= 114, 52 males, 62 females). No systematic reasons for attrition from 128 to 114 were found other than some families moved to places where they could no longer come to the university on an annual basis. The mean age for child participants in grade 2 was 92.75 months (SD= 3.74); mean age for child participants in grade 5 was 128.36 months (SD=3.70). Ethnicity of child participants in grade 2 was as follows: 64.8% Caucasian, 23.4% Asian-American, 6.3% Black-American, 2.3% Native American, .8% Hispanic, and 2.3% Other. Their mothers' highest educational attainment ranged from college (45.3%), to graduate degree (33.6%), community college/ vocational (11.7%), high school (7%), less than high school (0.8%), or unknown (1.6%). In grade 5 when some children were no longer able to participate (e.g., because of a move), ethnicity was as follows: 64.9% Caucasian, 24.6% Asian-American, 6.1% Black-American, 1.8% Native-American, and 2.6% Other. Mother's highest educational attainment ranged from college (44.7%), to graduate degree (35.1%), community college/vocational (9.6%), high school (7.9%), less than high school (1%), or unknown (1.8%). English was the first language for all participants who were fluent in English. None of the children qualified for free and reduced lunch.

Predictor Measures

Verbal comprehension—In second grade, three subtests of the Verbal Reasoning Factor of The *Wechsler Intelligence Scale for Children, 3rd edition (WISC-3*) (Wechsler, 1991) were given: similarities, vocabulary, and comprehension. In fifth grade, the same subtests for the Verbal Comprehension Index of the *Wechsler Intelligence Scale for Children, 4th edition (WISC 4*) (Wechsler, 2003) were given. For example, one task asks children to explain how two words are similar, another one asks them to define words, and one asks them to answer questions to show comprehension of the world. No reading or writing is needed for the assessment, which requires oral answers to aurally administered items. Raw scores were converted to a standard score (*M*=100, *SD*=15) for age for the Verbal Comprehension Factor/Index.

Phonological word form storage and processing—The *Comprehensive Test of Phonological Processing* (*CTOPP) Nonword Repetition* subtest (Wagner, Torgesen, & Rashotte, 1999) was given. Children listen to the test examiner say a pseudoword and are asked to repeat the word orally. Children do not have to read the word; so it is not a measure of decoding—pronouncing a written word. Raw scores were converted to scaled scores for age (*M*=10, *SD* =3).

Orthographic word form storage and processing—The *Orthographic Receptive Coding* test (Berninger, 2001) requires children to view a briefly displayed word, close eyes, and hold it in working memory while making judgments about all the letters in a word, a letter in a specific word position, or sequence of one or two letters within the word. Children do not need to decode the words. This measure, developed and validated in the University of Washington research program, used *z* scores (*M*=0, *SD*=1) for grade based on national norms created by the Psychological Corporation in the national standardization of the original PAL.

Morphological word form storage and processing—*The University of Washington (UW) Signals Test* (Nagy, Berninger, Abbott, Vaughan, & Vermeulen, 2003), which was used in second grade to assess morphological awareness, requires that the child choose the suffixed word that fits the blank in the sentence context. Correct answers reflect understanding how a suffix marks grammatical function. The University of Washington (UW) *Comes From Test* (Nagy, Berninger, & Abbott, 2006), which was used in fifth grade to assess morphological awareness, requires that children decide whether two words come from same word. For example, does builder come from build? Does corner come from corn? Correct answers reflect understanding of how the same spelling of a word part may or may not mark a morpheme. Understanding morphology beyond shared spellings is required. Children did not read or write the words or sentences in second grade or the word pairs in fifth grade; at each grade level the stimuli were read to them while they listened and viewed the words. These measures, which assess morphology in spoken and written words, were validated in the University of Washington research program as the best age-appropriate measures of morphology in the battery at the second and fifth grade levels. Raw scores were converted to *z*-scores (*M*=0, *SD* =1) using research norms.

Syntactic storage and processing of accumulating words—The *Clinical Evaluation of Language Fundamentals 3 (CELF-3) Formulated Sentences* (Semel, Wiig, & Secord, 1995) was given, which assesses a child's ability to create syntactically correct oral sentences from pictured and spoken words. No reading or writing is required for this task. For example, target pictured words are pronounced, and the child is asked to form an oral sentence using the stimuli[3]. Raw scores were converted to scaled score for age (*M*=10, *SD* =3).

Phonological loop—The *Rapid Automatized Naming* (RAN) test (Norton & Wolf, 2012; Wolf & Biddle, 1994) measures ability to integrate letter codes and name codes quickly in time. Scores are based on the amount of time the child takes to name rows of lower case letters as quickly as possible. This measure, which assesses a different skill than phonological memory or phoneme awareness, used prepublication measures and research norms from Wolf's lab at Tufts University to create *z*-scores for grade. Based on Elizabeth Wiig's insight (personal communication, at Arizona ASHA meeting in May, 2004), Baddeley, Gathercole, and Papagno's (1998) proposal that the phonological loop is really a cross-code language learning device, and structural equation modeling studies modeling RAN as phonological loop of working memory (Berninger et al., 2006), we interpret RAN letters as an indicator of the cross-code phonological loop for oral names and written letters.

Orthographic loop—The *Alphabet Writing* task (Berninger, 2001) requires the child to write the alphabet legibly and in order from memory. Scores are based on the number of letters written correctly in alphabetic order in the first 15 seconds, an index of automatic retrieval and production. This measure developed and validated in the University of Washington research program used *z* scores for grade (*M*=0, *SD* =1) based on national norms created by the Psychological Corporation in the national standardization of the original PAL.

Executive functions—The *Rapid Automatic Switching* (RAS) (Wolf, 1986; Wolf & Biddle, 1994) requires rapid switching between naming of letters and naming of numerals and thus assesses supervisory attention in verbal working memory (Altemeier et al., 2008). This test is an index of the child's ability to switch attention as orthographic stimuli to be named switch across categories. This measure used prepublication measures and norms from Wolf's Tufts University research group to create *z*-scores for grade.

Outcome Measures

Real word reading accuracy—The *Wechsler Individual Assessment Test, 2nd edition* (WIAT-II) Word Reading subtest (Wechsler, 2001) measures the accuracy of pronouncing real words on a list without context clues. Raw scores were converted to standard scores for age (*M*=100, *SD*=10).

[3]As heard and/or viewed single words accumulate in serial order, each is stored in working memory while the processing involved in constructing the sentence syntax unfolds over time.

Real word reading rate—The *Test of Word Reading Efficiency (TOWRE)* Sight Word Efficiency (Torgesen, Wagner, & Rashotte, 1999) measures the child's accuracy in pronouncing printed words in a list within a time limit of 45 seconds. Raw scores were converted to standard scores for age (*M*=100, *SD* =10).

Phonological decoding accuracy—*The WIAT-II Pseudoword Reading* subtest (Wechsler, 2001) requires a child to read a list of pronounceable non-words accurately, and, thus, is a measure of decoding. Raw scores were converted to standard scores for age (*M*=100, *SD* =15).

Phonological decoding rate—The *TOWRE Pseudoword Efficiency Test* (TOWRE) (Torgesen et al., 1999) requires a child to read a list of pronounceable non-words accurately within a 45 seconds time limit. Raw scores were converted to standard scores for age (*M*=100, *SD*=15).

Reading comprehension—The *Wechsler Individual Achievement Test, 2nd edition (WIAT-II)* Reading Comprehension subtest (Wechsler, 2001) requires the child to read different reading passages and give oral answers to oral questions about the text. Raw scores were converted to standard scores for age (*M*=100, *SD* =15).

Handwriting—The *PAL Copy Task B* (Berninger, 2001) requires the child to copy a paragraph as accurately as possible within a 90 second time limit, and thus assesses sustained handwriting from a model text. Raw scores were converted to z scores (*M*=0, *SD*=1) for grade based on national norms.

Spelling—The *WIAT II Spelling* (Wechsler, 2001) requires the child to spell, in writing, dictated real words pronounced alone and in sentence context for meaning clues. Scores for number of correctly spelled words were converted to standard scores for age (*M*=100, *SD* =15).

Composition—The *WIAT-II Written Expression* subtest (Wechsler, 2001) requires the child to perform three tasks in second grade–alphabet writing, word fluency, and sentence combining, and three other tasks in fifth grade – word fluency, sentence combining, and paragraph writing. Measures are scored using criteria in the test manual. Data are reported as standard scores (*M*=100, *SD* =15) for age.

Procedures

Administration of the test battery—Graduate research assistants administered the test battery at the university between the second and fourth month of second or fifth grade.

Data analyses—The Statistical Package for the Social Sciences (SPSS) software was used to perform separate correlational analyses for each predictor and outcome variable at each grade level. Scores for the 128 participants in second grade were entered in the correlations for grade 2 variables. Likewise, scores for the 114 participants remaining in fifth grade were entered in the grade 5 correlational analysis for that level.

Following correlational analysis, multiple regressions were performed separately for each dependent variable (outcome measures for real word reading accuracy and rate, phonological decoding accuracy and rate, reading comprehension, handwriting, spelling, and written expression), with the verbal comprehension factor/index), storage and processing units (phonological, orthographic, and morphological word forms and syntax), loops (phonological and orthographic), and executive function (rapid automatic switching) as the independent variables for predicting outcomes. Only those variables found to have a significant relationship with a given outcome variable in the correlational analyses were entered as predictors in the multiple regression analyses.

Results

Descriptive Statistics and Correlations

Table 1 reports the means and standard deviations for each measure at each grade level. Tables 2 and 3 report the correlations between each predictor and each outcome measure at each grade level. In Table 1, the predictors are described in reference to both the construct they assess and the test used to assess that construct. The negative signs for RAN and RAS result from the time scores for which a higher score is a worse score; the alphabet 15 score on the other hand is an accuracy score with time held constant.

Significant correlations between predictor and outcome measures at grade 2—See Table 1 for the constructs each test in Tables 2 and 3 assesses. As shown in Table 2, all predictors correlated significantly with real word reading accuracy and rate. All predictors except orthographic loop correlated significantly with pseudoword reading accuracy, and all predictors except phonological coding correlated significantly with pseudoword reading rate. All predictors were correlated with reading comprehension. As shown in Table 3, for sustained handwriting on the copy task, only orthographic coding, phonological loop, orthographic loop, and supervisory switching attention were significantly correlated with it. For spelling, all predictors were significantly correlated with it. For written expression all predictors except phonological coding were significantly correlated with it.

Significant correlations between predictor and outcome measures at grade 5—See Table 1 for constructs each test in Tables 4 and 5 assesses. As shown in Table 4, for real word reading accuracy, all predictors except orthographic loop were significantly correlated with it. For real word reading rate, all predictors except phonological coding were significantly correlated with it. For pseudoword reading accuracy, all predictors except phonological coding and orthographic loop were significantly correlated with it. For pseudoword reading rate, all predictors except phonological coding were significantly correlated with it. For reading comprehension, verbal reasoning and phonological, orthographic, morphological, and syntactic coding, but not the phonological or orthographic loops or supervisory switching attention, were significantly correlated with it. As shown in Table 5, orthographic coding, syntax, and orthographic loop were significantly correlated with sustained handwriting when copying text. All predictors except phonological coding were significantly correlated with spelling. All predictors except phonological loop were significantly correlated with written expression.

First Research Question: Variance Explained by Verbal Reasoning Alone or Combined with Multi-Component Working Memory

Correlations with Verbal Reasoning in Tables 2, 3, 4, and 5 were squared to determine how much variance was accounted for by Verbal Comprehension alone. R^2 for each of the multiple regressions in Tables 2, 3, 4, and 5 was used to determine how much variance was accounted for by Verbal Comprehensionplus Verbal Working Memory Components. Results, which are summarized in Table 6, show that consistently more variance was accounted for by Verbal Comprehension plus Verbal Working Memory Components than Verbal Comprehension alone. Overall, the combined Verbal Comprehension and Working Memory Predictors accounted for 30% to 69% of the variance, except for handwriting in fifth grade for which the combined predictors accounted for only 18% of the variance.

Second and Third Research Questions: Constant and Changing Unique Predictors in 2nd and 5th Grade

In addition, the unstandardized regression weights from the multiple regression findings in Tables 2, 3, 4, and 5 were used to determine which of the predictor variables explained unique variance in each reading and writing skill over and beyond their shared variance with the other predictors, that is answer the second research question. These results, which address the second research question, are summarized in Table 7 to facilitate ease of comparison within and across grade levels and reading and writing skills for purposes of answering the third research question. Overall, which predictors explained unique variance over and beyond the shared variance for predictors that correlated with a specific reading or writing skill tended to vary with specific reading and writing skills. They also varied across grade levels in sample in which the same children were compared to themselves during early childhood and then again during middle childhood. Individual differences in predictors of specific reading and writing skills appear to change dynamically over the formative years of literacy learning.

As shown in Table 6, of the 16 regressions (8 at each of two grade levels), verbal comprehension explained unique variance in all but 4 (75%). For *real word reading accuracy and rate*, phonological coding explained unique variance in second grade, but morphological coding did in fifth grade when words tend to be longer with more affixes. For *pseudoword reading accuracy*, in second grade, phonological, orthographic, and morphological coding, but in fifth grade, verbal comprehension, orthographic coding, and orthographic loop, explained unique variance. For *pseudoword reading rate*, in second grade, verbal reading, phonological and orthographic coding, and switching attention, but in fifth grade only verbal comprehension and switching attention, explained unique variance. For *reading comprehension*, oral verbal comprehension and phonological and morphological coding at both grade levels but orthographic coding in second grade and orthographic loop in fifth grade explained unique variance. Although orthographic coding and both loops explained unique variance in second grade *handwriting*, only orthographic coding did in fifth grade, consistent with handwriting being more than just a motor skill. For *real word spelling*, orthographic coding explained unique variance at both second and fifth grade, but morphological coding did as well in fifth grade. In second grade, verbal comprehension, syntactic coding, and orthographic loop uniquely explained *written composition*, but in fifth grade only orthographic coding did.

Fourth Research Question: Using Beta Weights to Predict Observed Reading and Writing Achievement in Individual Students

To evaluate potential educational applications of these findings to individual students, unstandardized regression weights in the multiple regression and the standardized beta weights in Tables 2 and 3 (grade 2) and 4 and 5 (grade 5) were used. The latter permit comparison across tests that yield scores on different scales (standard scores M=100, SD=15; or scaled scores M=10, SD=3; or z-scores M=0, SD=1) to predict expected outcome scores for individual students. These predicted outcomes can be compared to observed outcomes to determine if an individual student is making reasonable progress in a specific reading or writing skill. Two cases for each of two reading or writing skills at the second and fifth grade levels are presented for which expected outcomes based on verbal reasoning alone or verbal reasoning plus components of the working memory language learning system are compared to the observed outcome.

Second-grade real word reading—Case 1's predicted outcome based on verbal reasoning alone was 99, but based on verbal reasoning plus working memory components was 84; actual outcome was 88;. Case 2's predicted outcome based on verbal reasoning alone was 96, but based on verbal reasoning plus working memory components was 86; actual outcome was 78. In both cases, the observed outcome was closer to the predicted outcome based on verbal reasoning plus working memory components. In both cases the actual outcome was in the bottom quartile (case 1, low average; case 2, below average). By examining relative strengths in the profile of skills, educational professionals have more information about whether current response to instruction achievement level is at expected level. The profile also provides clues for individually tailoring future instruction to any relative weaknesses in the verbal working memory language learning profile, regardless of whether the child appears to be doing reasonably well (case 1) or is below expected levels for both kinds of predictions (case 2).

Second-grade pseudoword reading—Case 1's predicted outcome based on verbal comprehension alone was 97, but based on verbal comprehension plus working memory components was 87; actual outcome of 87. Case 2's predicted outcome based on verbal comprehension alone was 99, but based on verbal comprehension and working memory components was 88; actual outcome was 84. In both cases, the observed outcome was closer to the predicted outcome based on verbal comprehension plus working memory components. However, in Case 1 achievement was exactly at the level predicted by verbal comprehension plus working memory components, but in Case 2 was slightly below the expected level predicted by verbal comprehension plus working memory components, even though it was a full standard deviation below the expected level based on verbal comprehension alone. Again, future instruction might target skills that are underdeveloped in the profile of skills to optimize literacy development, but both teachers and parents should recognize that currently the child is functioning at or near expected level.

Fifth grade—spelling—Case 1's predicted outcome based on verbal comprehension alone was 107, but based on verbal comprehension plus working memory components was 96; actual outcome was 94. Case 2's predicted outcome based on verbal reasoning alone was 106, but based on verbal comprehension plus working memory components was 84; actual outcome was 90. In both cases, the observed outcome was closer to the predicted outcome based on verbal comprehension plus working memory components. In contrast to Case 1 who was in the average range, Case 2 was in the low average range. However, in both cases the child might respond to future instruction individually tailored to the weaknesses in the assessed working memory skills in the model.

Fifth grade—written expression—Case 1's predicted outcome based on verbal comprehension alone was 101, but based on verbal comprehension plus working memory components was 90; actual outcome was 86. Case 2's predicted outcome based on verbal comprehension alone was 107, but based on verbal comprehension plus working memory components was 92; actual outcome was 83. In both cases, the observed outcome was closer to the predicted outcome based on verbal comprehension plus working memory components, but both cases might respond to future instruction individually tailored to the weaknesses in the assessed skills in the profile.

These examples were chosen to show how predictions based on verbal comprehension alone may be the same, but more often the predictions based on verbal comprehension (i.e., cognitive ← → linguistic translation) plus components of working memory, which support language learning, were closer to the observed levels in typically developing language learners. This finding is relevant to translation science—showing that a theoretically grounded model makes empirical predictions that are educationally relevant.

Discussion

Significance of the Research Findings

First research question related to amount of variance explained—Consistent with prior research showing a relationship between Verbal Comprehension and achievement levels in reading and writing (see Introduction), WISC Verbal Comprehension Factor/ Index was significantly correlated with all reading and writing outcomes used in multiple regression except handwriting (see Tables 2, 3, 4, and 5). The lack of significant relationship between Verbal Comprehension and handwriting meshes with findings across multiple studies in one programmatic line of research (Berninger, 2009). One explanation for this replicated findings is that letter writing, a subword skill, does not connect with levels or units of language that have corresponding cognitive representations—words, sentences, and text. This explanation is consistent with conceptualizing Verbal Comprehension Factor/ Index not a measure of pure cognition but rather as a measure of cognitive ← → linguistic translation (see Introduction and Berninger et al., 2012; Stahl & Nagy, 2005). This alternative conceptualization of the Verbal Comprehension Factor/Index does not detract from its usefulness in assessment of reading and writing achievement, but rather has implications for its interpretation and application. As shown in Table 6, the Verbal Comprehension Factor/ Index accounted for sizable variance in the reading and writing achievement outcomes other than handwriting. At the second grade, Verbal Comprehension accounted for 10.2% to 31.4% of the variance in word-level skills and 16% to 47.6% of the variance in text-level skills; at the fifth grade level, Verbal Comprehension accounted for 23% to 41% of the variance in word-level skills and 14.4% to 52% of the variance of text-level skills. Consistently across grade level Verbal Comprehension only explained about 2% of the variance in sub-word sustained letter writing.

However, the important finding is that substantially more variance can be explained in the variation in reading and writing outcomes if both Verbal Comprehension and Working Memory Components Supporting Language learning are used as predictors. As shown in Table 6, when the combined predictors were used, at the word level 51% to 65% of the variance and at the text level 64% to 69% of the variance could be explained for second graders; and at the word level 42% to 68% of the variance and at the text level 30% to 62% of the variance could be explained for fifth graders. This finding of better prediction of specific reading and writing outcomes when both Verbal Comprehension and Working Memory Components are used has theoretical and practical significance.

The theoretical significance is that both ability in cognitive ← → linguistic translation and working memory components supporting language learning may be related to learning to read and write at the word-, syntax-, and text-levels of language. The combination of the cognitive ← → linguistic translation and the working memory components, which are behavioral markers of genetic mechanisms, may be the language learning mechanism that Chomsky (1957, 2006) proposed and Snow (1983) showed develops as the language learner interacts with the social environment. If so, the deep structure may not be in the language per se, but rather in these mechanisms that support communication among the cognitive and linguistic worlds in the human mind (see Berninger et al, 2012). The practical significance is that although calculating discrepancy between cognitive ability and reading or writing achievement has not been shown to be valid for identifying students who have learning disabilities (e.g., Stuebing, Fletcher, LeDoux, Lyon, Shaywitz, & Shaywitz, 2002), the Wechsler Verbal Comprehension Factor (Wechsler, 1991) or Index (Wechsler, 2003), especially when used with the measures of the multiple components of working memory, may predict where language learners fall along the distribution of reading or writing skill at a particular time in their language development.

Second research question regarding which predictors explain unique variance in early childhood and middle childhood—As summarized in Table 6, for each reading and writing outcome at the second grade level and the fifth grade level, different predictors were found to explain unique variance in different outcomes. The theoretical significance is that different cognitive and language skills in a language learning mechanism may be relevant for predicting specific reading and writing skills during early childhood or middle childhood. Given that phonological word-form coding and phonological loop explained unique variance in many of the reading and writing outcomes, a phonological core (coding and loop) in working memory may underlie reading and writing acquisition for many second and fifth graders—not just those with specific learning

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disabilities (cf., Morris et al., 1998; Swanson & Siegel, 2001). Yet, consistent with prior converging evidence, verbal working memory components including orthographic and morphological coding, an orthographic loop, and supervisory switching attention may also predict individual differences in specific reading and writing skills in second and fifth graders, as results of the current study show. The practical significance is that if studies like the current one can be replicated on other samples, then screening measures could be developed that are individually tailored to specific reading or writing skills for identifying students in general education for differentiated instruction in specific reading and writing skills at a particular grade level. Such an approach might contribute to optimizing reading and writing achievement among typically developing language learners as well as preventing severe learning disabilities in those at risk for specific learning disabilities.

Third research question related to developmental changes in predictor-outcome relationships—As children move from the learning-to-read or write to the reading- or writing- to- learn stages of literacy development, some relationships between specific predictors and specific reading or writing skills remain the same and some change. Table 7 is designed to provide both researchers and practitioners with an overview of which predictors explain unique variance both in early and middle childhood and which explain unique variance at one developmental level but not the other. As summarized in Table 7, these unique predictors might inform design of curriculum and instruction for specific reading and writing skills at specific grade levels. The child's profile of relative strengths and weaknesses on the verbal working memory components supporting language learning may be relevant to planning differentiated instruction tailored to the instructional needs of individual students for specific reading and writing skills and also assessing their response to instructional intervention (RTI).

Evidence-based instructional resources are now widely available for English speakers in United States that could be used for planning and implementing differentiated instruction linked to RTI learning profiles for verbal working memory components both in early childhood and middle childhood: For teaching *phonological coding* (e.g., Adams, Foorman, Lundberg, & Beeler, 2012); *morphological coding* (e.g., Henry, 1990, 2010; Nunes & Bryant, 2006), *orthographic coding* (e.g., Berninger & Abbott, 2003; Fry, 1996), and their interrelationships (e.g., Bear, Ivernezzi, Templeton, S., & Johnston, 2000; Wasowicz, Apel, Masterson, & Whitney, 2004), as well as *syntax coding* (e.g., Beck & McKeown, 2001, 2004a). Developing children also benefit from *vocabulary instruction* that promotes not only cognitive (verbal reasoning) but also reading and writing skills (Beck & McKeown, 2004b, 2007; Beck, McKeown, & Kucan, 2003; Stahl & Nagy, 2005). Evidence-based lessons are available for teaching the *various reading and writing subskills* to students during early childhood (e.g., Beck & McKeown, 2004; Blachman, Tangleman, 2008) and middle childhood (Denton et al., 2012) as well as early childhood to adult years (e.g., Graham, MacArthur, & Fitzgerald, 2007; Wilson, 1998; Wilson Language Training Corporation. 2004–2010; Troia, 2009). Instructional resources are also now widely available for developing and *exercising the* phonological loop (e.g., Read Naturally, 1997–2008) and are increasingly available for developing and *exercising the orthographic loop* (e.g., Berninger & Abbott, 2003). Lessons based on peer reviewed research are also now available for developing *supervisory attention for switching attention* by alternating colors of graphemes (1- and 2- letter units) in teaching application of grapheme-phoneme correspondences to oral decoding of written words (Berninger & Abbott, 2003). *Cross-national work groups might compile such evidence-based approaches across countries and languages.*

Fourth research question—translational science—

The fourth research question was related to translational science from research into practice for individual students. The results of the individual cases presented for using beta weights for the best predictors for each reading and writing skill for predicting reasonable levels of achievement in individual readers or writers suggest promise for this approach, at least for the normal variation within typically developing readers and writers.

Validity of Research Findings

Internal, construct, and statistical validity—

Shadish, Cook, and Campbell (2002) called attention to four kinds of validity evidence in research designs: internal, construct, statistical, and external. This study was not designed to draw cause-effect conclusions related to *internal validity*. It was not an instructional study with random assignment to condition. Rather the goal was to validate a construct—which predictor or combined predictors accounted for the most variance in specific reading and writing skills at two grade levels—one in early childhood and one in middle childhood. Although the percent variance accounted for was consistently higher for the combined predictors, which of the working memory components was correlated with or explained unique variance varied across specific reading or writing skills and grade levels. Power analyses in prior studies had shown that sample size was sufficient to identify reliable statistically significant relationships between the predictors and outcome measures, consistent with adequate *statistical validity*.

External validity—

Generalization of results from the current study, *external validity*, should be restricted to students at the second and fifth grade level who are not living in poverty, who are not living in families that are recent immigrants to the United States, and who are not English language learners. Also, the results were somewhat different for the various reading and writing outcomes and grade levels. Thus, results should also be carefully generalized by skill and grade level of children.

Predicting Reasonable Levels of Reading and Writing Achievement

The current study was conducted in the US to address issues related to normal variation, that is, individual differences, in language learners. The models evaluated could be applied to other student populations as well. For example, students with disabilities in the United States have legally protected civil rights referred to as Free and Appropriate Public Education (FAPE). The model in the current study may also be useful for predicting reasonable levels of achievement in young adults in families with multi-generational history of dyslexia (submitted), student athletes with academic difficulties (in progress), school age children in middle childhood and early adolescence with persisting writing and reading disabilities (e.g., Berninger, Swanson, & Griffin, in press), and twice exceptional students with dyslexia (Berninger & Abbott, 2013). However, whether such a model will work requires crossvalidation across research groups and educational settings within the US. Also, much more research is needed to evaluate whether it may generalize to other countries and languages.

Limitations and Future Directions

Although the combined predictors explained sizable variance in the reading and writing outcomes, they did not account for 100% of the variance. Future research should investigate which other variables might be added to explain all the variance in specific reading and writing outcomes at specific grade levels not just grades 2 and 5. Additional research is also needed to determine whether the results replicate and generalize to other samples with similar and also contrasting student populations. Also, other measures of verbal cognition might be evaluated in the model in future studies. Furthermore, given the documented role of poverty in achievement gaps (Duncan & Murnane, 2011), more research is needed for predicting and facilitating reading and writing achievement in those living in poverty for whom achievement gaps are the widest to supplement studies like the current one based on students not living in poverty. Future research might also examine effects of designing individually tailored instruction on the basis of one or more weaknesses in the individual's profile for verbal reasoning, word and syntax coding, loops and switching attention and assessing response to such instruction.

Results of such studies could be used to optimize the achievement of ALL students, provide their parents evidence-based feedback about whether their children are reading and writing at reasonable levels, and evaluate teacher effectiveness fairly. Given the enormous individual differences among students in initial levels of achievement at the beginning of the school year, teachers should evaluate change from the beginning to end of the year for individual students and not only final performance of all students on average at the end of the school year. Teachers should not be held accountable for the individual differences students bring with them to formal education. They should be held accountable that each student makes progress from the beginning of the school year to the end of the school year. Not all students start at the same starting line, and education should be a journey, not a race, to engage and construct individual students' minds during early and middle childhood. Teachers who learn to guide that journey effectively, regardless of where a student starts each year, should be highly valued.

Conclusions

Francis and colleagues (2005) argued for the need for more precise identification of children's learning disabilities. Their insights should be extended to apply more precise linking of assessment and instruction in RTI for ALL students not just those at risk for specific learning disabilities, which is why this programmatic research on predicting reasonable levels of achievement for RTI began with typically developing readers and writers. The current study provides evidence about significant predictors of reading and writing outcomes that might inform designing and evaluating response to reading and writing instruction during early childhood and middle childhood. Considerable research has focused on these issues for reading. The current study includes reading but extends the study of individual differences in typically developing second and fifth graders to writing. The *No*

Child Left Behind Act of 2001 (NCLB, 2003) mandated that all schools in the United States with federal funding adopt the use of *scientifically based* reading instruction with the aim of ensuring reading success for all children. However, this legislation *left writing behind* and focused only on reading. Both writing and reading are needed for academic success across content areas and to pass many of the high-stakes tests (e.g., Shanahan, 2006). In addition, this legislation did not deal with the practical issue of how educators can operationalize reading success when most human traits, including reading, exhibit normal variation. On a probability basis, it simply is not possible for all children to read (or write) at the 99th %tile or even above the mean. If a cut-off is used (those above pass the test and those below fail the test), then valuable information is lost about individual differences among students related to relative level of skill development compared to age or grade peers in individuals' profiles of reading and writing skills that can be used for planning, implementing, and evaluating RTI for differentiated instruction in general education.

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Highlights

- We evaluate best predictors of reading and writing skills that distribute normally.
- Working memory components predicted more variance than verbal reasoning.
- Combined working memory components and verbal reasoning explained most variance.
- Predictors explaining unique variance varied by skill and grade (2nd or 5th).
- Combined model predictions were closer to individual student's actual achievement.

Table 1

Means and (SDs) for Each Measure by Grade Level of Participants (See Table Notes).

Measures **Working Memory Component**	**Second Graders** **M (SD)**	**Fifth Graders** **M (SD)**
Predictor Measures		
[a] WISC Verbal Comprehension (*Similarities, Vocabulary, Comprehension*)	114.65 (15.74)	115.31 (13.67)
[b] CTOPP Nonword Repetition (*Phonological Word Form*)	9.51 (2.21)	9.95 (2.52)
[c] PAL Receptive Coding (*Orthographic Word Form*)	0.03 (0.91)	0.22 (1.02)
[c] UW Morphological Signals 2nd	0.07 (1.01)	0.00 (1.02)
[c] UW Comes From 5th (*Morphological Word Form*)		
[b] CELF3 Formulated Sentences (*Accumulating Words in Oral Syntax*))	10.90 (2.67)	12.02 (2.66)
[c] Prepub Wolf RAN letters (*Phonological Loop*)	−0.19 (0.78)	−0.10 (0.97)
[c] UW Alphabet 15 seconds (*Orthographic Loop*)	0.30 (0.90)	0.04 (0.97)
[c] Prepub Wolf RAS (*Switching Attention*)	0.22 (1.37)	−0.10 (0.91)
Achievement Outcome Measures		
[a] WIAT2 Word Reading (*accuracy reading real words*)	113.64 (14.07)	113.07 (11.58)
[a] WIAT2 Pseudoword Reading (*accuracy reading pseudowords*)	111.88 (14.78)	108.32 (8.60)
[a] TOWRE Sight Words (*rate reading real words*)	110.50 (13.86)	109.61 (11.87)
[a] TOWRE Phonemic Reading (*rate reading pseudowords*)	107.71 (14.88)	110.46 (14.67)
[c] UW Copy Task (*copy paragraph from model*)	0.47 (1.17)	0.32 (1.07)
[a] WIAT2 Reading Comprehension (*answer questions about text*)	110.77 (11.59)	116.30 (8.28)
[a] WIAT 2 Spelling (*spelling dictated words*)	109.10 (13.05)	108.11 (14.14)
[a] WIAT2 Written Expression (*word-, sentence-, text-composing*)	102.86 (13.48)	108.04 (12.40)

Notes. (

[a]Standard Score, *M*=100, *SD*=15;

[b]Scaled Score, *M*=10, *SD*=3;

[c]*z*-score, *M*=0, *SD*=1)

Table 2

Grade 2: Correlations with Criteria and for Multiple Regression Model Unstandardized Coefficients, Standardized Coefficients, R^2 for Model, and Associated F Value for Real Word and Pseudoword Accuracy and Rate and Reading Comprehension (See Table 2 for constructs for each test).

	WIAT 2 Real Word Accuracy		WIAT 2 Pseudoword Accuracy		TOWRE Sight Word Efficiency		TOWRE Phonemic Reading Efficiency		WIAT 2 Reading Comprehension	
	Zero-order correlation	Model 1 Standardized β weights	Zero-order correlation	Model 1 Standardized β weights	Zero-order correlation	Model 1 Standardized β weights	Zero-order correlation	Model 1 Standardized β weights	Zero-order correlation	Model 1 Standardized β weights
WISC3 Verbal Comprehension	0.56 ***	0.33***	0.32***	0.00	0.50***	0.18*	0.47***	0.15*	0.69***	0.541***
CTOPP Nonword	0.29 ***	0.20**	0.25**	0.17*	0.19*	0.13*	0.18	0.13*	0.25**	0.13*
Receptive Coding	0.58***	0.35 ***	0.63***	0.50 ***	0.54***	0.27***	0.60***	0.35***	0.46***	0.19**
Signals	0.50***	0.14	0.48***	0.19*	0.49**	0.11	0.50**	0.12	0.56***	0.18**
Formulated Sentences	0.27**	−0.01	0.20*	0.07	0.32 **	0.09	0.26 **	0.05	0.48***	0.17
RAN Letters	−0.35***	0.10	−0.33***	0.03	−0.50***	0.05	−0.56***	−0.13	−0.41***	−0.03
Alphabet 15ecs	0.22*	0.03	0.15	−0.09	0.31 *	0.05	0.26 *	−0.02	0.22*	−0.01
RAS Letters, Digits	−0.49***	−0.26 *	−0.44***	−0.22	−0.65***	−0.45**	−0.65***	−0.31 **	−0.51***	−0.19
F		(8,96)=18.16***		(8,99)=14.34 ***		(8,99)=20.85 ***		(8,98)=22.37 ***		(8,95)=26.06***
R^2		0.60		0.54		0.63		0.65		0.69
		Unstandardized b-weights		Unstandardized b-weights		Unstandardized b-weights		Unstandardized b-weights		Unstandardized b-weights
Intercept		69.27		97.32		80.35		79.54		61.06
WISC3 Verbal Comprehension		0.29***		0.00		0.16*		0.15*		0.31***
CTOPP Nonword		1.27**		1.13*		0.82*		0.88*		0.68*
Receptive Coding		5.32***		7.69***		3.95***		5.48***		2.39**
Signals		1.89		2.82*		1.52		1.75		2.08*
Formulated Sentences		−0.08		0.37		0.49		0.28		0.72*
RAN Letter		1.84		0.56		0.94		−2.55		−0.45
Alphabet 15secs		0.49		−1.49		0.76		−0.34		−0.18
RAS Letters, Digits		−2.67*		−2.43		4.61**		−3.38**		1.78

* $p<.05$;

** $p<.01$;

*** $p<.001$

Table 3

Grade 2: Correlations with Criteria and for Multiple Regression Model Unstandardized Coefficients, Standardized Coefficients, R^2 for Model, and Associated F value for Handwriting on Copy task, Spelling, and Written Expression (Composition). (See Table 2 for constructs for each test).

	Copy B Task		WIAT 2 Spelling		WIAT 2 Written Expression	
	Zero-order correlation	Model 1 Standardized β weights	Zero-order correlation	Model 1 Standardized β weights	Zero-order correlation	Model 1 Standardized β weights
WISC3 Verbal Comprehension	0.14	−0.01	0.47***	0.18*	0.40***	0.24**
CTOPP Nonword	−0.02	0.01	0.16*	0.07	0.09	0.04
Receptive Coding	0.39***	0.24*	0.55***	0.37***	0.28**	0.05
Signals	0.14	−0.02	0.45***	0.10	0.20*	−0.09
Formulated Sentences	0.04	−0.06	0.37***	0.17*	0.46***	0.21**
RAN Letters	−0.47***	−0.38**	−0.35***	0.08	−0.37***	−0.06
Alphabet 15sec	0.39***	0.23*	0.32***	0.09	0.71***	0.60***
RAS Letters, Digits	−0.40***	0.06	−0.45***	−0.21	−0.37***	−0.02
F		(8,99)=6.19*		(8,99)=12.92***		(8,96)=21.81***
R^2		0.33		0.51		0.64
		Unstandardized b-weights		Unstandardized b-weights		Unstandardized b-weights
Intercept		0.68		78.91		62.54
WISC3 Verbal Comprehension		0.00		0.15*		0.21**
CTOPP Nonword		0.00		0.42		0.22
Receptive Coding		0.30*		5.10***		0.65
Signals		−0.03		1.35		−1.18
Formulated Sentences		−0.03		0.85*		1.04*
RAN Letters		−0.58**		1.34		−0.95
Alphabet 15sec		0.29*		1.37		9.17***
RAS letters, digits		0.05		−2.05		−0.20

* $p<.05$;

** $p<.01$;

*** $p<.001$

Table 4

Grade 5: Correlations with Criterion and for Multiple Regression Model Unstandardized Coefficients, Standardized Coefficients, R2 for Model, and Associated F value for Real Word and Pseudoword Reading Accuracy and Rate and Reading Comprehension (See Table 2 for constructs for each test.)

	WIAT 2 Real Word Accuracy		WIAT 2 Pseudoword Accuracy		TOWRE Sight Word Efficiency		TOWRE Phonemic Reading Efficiency		WIAT 2 Reading Comprehension	
	Zero-order correlation	**Model 1 Standardized β weights**	**Zero-order correlation**	**Model 1 Standardized β weights**	**Zero-order correlation**	**Model 1 Standardized β weights**	**Zero-order correlation**	**Model 1 Standardized β weights**	**Zero-order correlation**	**Model 1 Standardized β weights**
WISC 4 Verbal Comprehension	0.64 ***	0.36 ***	0.48***	0.22 *	0.50***	0.24 **	0.54***	0.34 ***	0.72***	0.55***
CTOPP Nonword	0.20*	0.04	0.12	0.01	0.16	−0.03	0.10	−0.05	0.28**	0.17*
Receptive Coding	0.54***	0.24 **	0.49***	0.28 **	0.50***	0.07	0.50***	0.10	0.28**	−0.03
Comes From	0.53***	0.27 **	0.38***	0.20	0.34***	0.20 *	0.26 **	0.07	0.56***	0.26**
Formulated Sentences	0.31***	0.04	0.28**	0.08	0.22 *	0.06	0.27 **	0.10	0.35***	0.06
RAN Letters	−0.27**	−0.01	−0.24**	−0.04	−0.63***	−0.25 **	−0.53***	−0.10	−0.11	−0.10
Alphabet 15ecs	0.07	−0.13	−0.02	−0.21 *	0.33***	0.07	0.20 *	−0.02	−0.06	−0.20**
RAS Letters, Digits	−0.33***	−0.22 *	−0.32***	−0.20	−0.65***	−0.41 ***	−0.64***	−0.49 ***	−0.05	0.05
F		(8,85)=15.20***		(8,84)=7.57 ***		(8,85)=22.15 ***		(8,84)=18.21 ***		(8,85)=17.51***
R^2		0.59		0.42		0.68		0.63		0.62
		Unstandardized b-weights		Unstandardized b-weights		Unstandardized b-weights		Unstandardized b-weights		Unstandardized b-weights
Intercept		73.09		88.02		82.44		62.95		70.46
WISC 4 Verbal Comprehension		0.31***		0.14*		0.21**		0.37***		0.33***
CTOPP Nonword		0.17		0.03		−0.13		−0.29		0.55*
Receptive Coding		2.92**		2.50**		0.86		1.63		−0.22
Comes From		3.11**		1.67		2.28*		0.99		2.13**
Formulated Sentences		0.16		0.26		0.26		0.53		0.18
RAN Letters		−0.11		−0.40		−3.03**		−1.49		−0.86
Alphabet 15sec		−1.59		−1.86*		0.84		−0.30		−1.74**
RAS Letters, Digits		−2.79*		−1.93		−5.36***		−7.89***		0.42

* $p<.05$;

** $p<.01$;

*** $p<.001$

Table 5

Grade 5: Correlations with Criterion and for Multiple Regression Model Unstandardized Coefficients, Standardized Coefficients, R2 for Model, and Associated F Value for Handwriting (Copy), Spelling, and Written Expression (Composition) (See Table 2 for constructs for each test).

	Copy B		WIAT 2		WIAT 2	
	Task		Spelling		Written Expression	
	Zero-order correlation	Model 1 Standardized β weights	Zero-order correlation	Model 1 Standardized β weights	Zero-order correlation	Model 1 Standardized β weights
WISC 4 Verbal Comprehension	0.16	0.05	0.48***	0.19*	0.38***	0.23
CTOPP Nonword	0.02	−0.05	0.16	0.00	0.18*	0.05
Receptive Coding	0.32***	0.29*	0.61***	0.34***	0.46***	0.31**
Comes From	0.05	−0.14	0.40***	0.20*	0.25**	0.00
Formulated Sentences	0.25**	0.19	0.23*	0.02	0.23*	0.05
RAN Letters	−0.04	0.19	−0.34***	0.08	−0.14	0.20
Alphabet 15sec	0.18*	0.17	0.17*	−0.04	0.20*	0.11
RAS Letters, Digits	−0.12	−0.10	−0.49***	−0.40***	−0.26**	−0.21
F		(8,83)=2.24*		(8,85)=12.73***		(8,85)=4.53***
R^2		0.18		0.54		0.30
		Unstandardized b-weights		Unstandardized b-weights		Unstandardized b-weights
Intercept		−0.95		82.51		77.82
WISC 4 Verbal Comprehension		0.00		0.20*		0.21
CTOPP Nonword		−0.02		−0.04		0.26
Receptive Coding		0.33*		5.15***		4.10***
Comes From		−0.14		2.79*		0.00
Formulated Sentences		0.08		0.13		0.25
RAN Letters		0.21		1.19		2.59
Alphabet 15sec		0.19		−0.52		1.38
RAS Letters, Digits		−0.11		−6.25***		−2.89

* $p<.05$;

** $p<.01$;

*** $p<.001$

Table 6

Percent Variance Explained by Verbal Comprehension Alone and by Verbal Comprehension Plus Verbal Working Memory Components (See Table Notes.)

Outcome	% Variance	
	Verbal Comprehension Alone	Verbal Comprehension + Verbal Working Memory Components
Second Grade		
Word Reading		
[a] Real Word accuracy	31.4%	60%
[b] Real Word rate	25%	63%
[a] Pseudoword accuracy	10.2%	54%
[b] Pseudoword rate	22.1%	65%
Reading Comprehension		
[a] Reading Comprehension	47.6%	69%
Writing		
[c] Handwriting	2%	33%
[a] Spelling	22.1%	51%
[a] Composing	16%	64%
Fifth Grade		
[a] Real Word accuracy	41%	59%
[b] Real Word rate	25%	68%
[a] Pseudoword accuracy	23%	42%
[b] Pseudoword rate	29%	63%
[a] Reading Comprehension	52%	62%
[c] Handwriting	2.6%	18%
[a] Spelling	23%	54%
[a] Composing	14.4%	30%

Notes.

[a] *WIAT2*,

[b] *TOWRE*,

[c] UW Writing Battery

Table 7

Unique Predictors within and across Grade Levels for Specific Reading and Writing Skills

Unique Predictors
WIAT2 Real Word Reading Accuracy
Second Grade WISC3 verbal reasoning, CTOPP phonological coding, PAL orthographic coding, RAS switching attention
Fifth Grade WISC4 verbal reasoning, PAL orthographic coding, UW morphological coding, RAS switching attention
TOWRE Real Word Reading Rate
Second Grade same as for accuracy
Fifth Grade same as for accuracy except RAN phonological loop replaced PAL orthographic coding
WIAT2 Peudoword Reading Accuracy
Second Grade CTOPP phonological coding, PAL orthographic coding, and UW morphological coding
Fifth Grade WISC4 verbal reasoning, PAL orthographic coding, Alph 15 orthographic loop
TOWRE Pseudoword Reading Rate
Second Grade WISC3 verbal reasoning, CTOPP phonological coding, PAL orthographic coding, RAS switching attention
Fifth Grade WISC4 verbal reasoning, RAS switching attention
WIAT2 Reading Comprehension
Second Grade WISC3 verbal reasoning, CTOPP phonological coding, PAL orthographic coding, and UW morphological coding
Fifth Grade WIS4 verbal reasoning, CTOPP phonological coding, UW morphological coding, Alph 15 orthographic loop
UW Sustained Handwriting (Copy)
Second Grade PAL orthographic coding, RAN phonological loop, Alph 15 orthographic loop
Fifth Grade PAL orthographic coding
WIAT2 Spelling
Second Grade WISC3 verbal reasoning, PAL orthographic coding, CELF3 syntactic coding
Fifth Grade WISC4 verbal reasoning, PAL orthographic coding, UW morphological coding
WIAT2 Written Composition
Second Grade WISC3 verbal reasoning, CELF3 syntactic coding, Alph 15 orthographic loop
Fifth Grade PAL orthographic coding