1-1-2011

An examination of multiple predictors of orthographic functioning.

Glenn R Mesman

Michelle Y. Kibby
Southern Illinois University Carbondale, mkibby@siu.edu

Recommended Citation

Mesman, Glenn R and Kibby, Michelle Y. "An examination of multiple predictors of orthographic functioning.." *Journal of Learning Disabilities* 44, No. 1 (Jan 2011): 50-62. doi:10.1177/0022219410371675.

Published in final edited form as:
J Learn Disabil. ; 44(1): 50–62. doi:10.1177/0022219410371675.

An Examination of Multiple Predictors of Orthographic Functioning

Glenn R. Mesman and **Michelle Y. Kibby**
Southern Illinois University, Carbondale

Abstract

The purpose of this study was to compare three variables in terms of how well they predict orthographic functioning. To this end, we examined the relative contributions of rapid naming, exposure to print, and visual processing to a composite of orthographic functioning in a heterogeneous group of 8- to 12-year-old children. Hierarchical regression revealed that rapid naming, exposure to print, and visual processing were each individually predictive of orthographic functioning when controlling for the other variables. Thus, it appears that both linguistic and visual abilities are related to orthographic functioning.

There is a substantial amount of research indicating phonological processing is poor in individuals with reading disorders (For reviews, see Snowling, 1995; Stanovich, 1985; Vellutino, Fletcher, Snowling, & Scanlon, 2004; Wagner & Torgesen, 1987). Despite the extensive literature supporting poor phonological processing as a potential etiology of dyslexia, these skills do not explain all the variance in reading abilities, and there may be unique variance unaccounted for by phonological processing (Cunningham, Perry, & Stanovich, 2001). Thus, a separate, yet related, line of research has focused on another factor that may contribute to dyslexia: poor orthographic functioning (Berninger, 1994; Olson, Forsberg, Wise, & Rack, 1994). Orthographic functioning often has been linked to irregular orthography. Therefore, it may be particularly important for reading in English, as approximately 50% of the words in the English language cannot be decoded through sound-symbol correspondence (Kessler & Treiman, 2003).

Even though there is increasing awareness about the importance of orthographic functioning for word identification ability, less research has examined the various contributors to orthographic functioning. To date, various predictors have been examined, but no one to our knowledge has systematically tested these predictors in one study to assess how well each explains orthographic functioning in comparison to the others. Hence, this is the goal of our study. Such predictors include rapid naming, print exposure, and visual processing. Other theorists, however, suggest that there may be additional factors related to orthographic functioning. For example, Share (1995) in his experimental self-teaching research suggested that phonological recoding of novel letter-strings is essential to orthographic learning. The predictors we tested were of particular interest because, although it has been suggested that rapid naming and exposure to print are related to orthographic functioning when tested individually, no study has systematically compared them to determine their relative importance. Moreover, research on visual processing has remained disparate in its findings. Thus, we chose to determine how well these three aspects predict orthographic functioning in comparison to each other. Phonological processing is commonly accepted as a predictor of orthographic functioning, partly based upon the work of Share; thus, we did not test phonological processing or decoding specifically, but we statistically controlled it instead.

Contribution of Orthographic Functioning to Reading Ability

Over the years there have been a variety of tasks used to assess orthographic functioning. As there are various names for very similar tasks, we will use the terminology used by the researchers when describing their tasks. The homophone choice test stems from the work of Olson, Kliegl, Davidson, and Foltz (1985) and requires that a person select the appropriately-spelled word from a choice of a real word and a pseudoword that is phonetically equivalent to it called a pseudohomophone (e.g, rume/room, boal/bowl). In the orthographic choice test (Stanovich & West, 1989), a person must read a question and choose the correct answer from two homophones (e.g., rose/rows, tail/tale). An experimental spelling test developed by Mann, Tobin, and Wilson (1987) also has been used as a measure of orthographic functioning. On this type of spelling test, irregular words were chosen so that a person must use orthographic abilities to correctly spell the word (e.g., people). All of these measures focus on commonly held views of what orthography includes (irregular words and homophones). Another orthographic functioning measure is a letter-string task called the Colorado Perceptual Speed Test (CPST; DeFries, Singer, Foch, & Lewitter, 1978). To complete this test, a person must choose a string of letters and occasionally numbers (e.g., mn6v) from a grouping of four other similar strings that is the exact match to the model letter-string. The word-likeness task is another measure that is commonly used to assess orthographic functioning. There are at least two versions of this measure (Stanovich & Siegel, 1994; Treiman, 1993), but they each assess an individual's knowledge of English letter patterns. The person completing the task is shown a series of paired pseudowords, one containing a legal letter pattern and the other a letter pattern that is rarely found in the English language (e.g., thomer/hretmo). The individual is instructed to identify the item that looks “more like a real English word” (Treiman, 1993, p. 167).

Stanovich and West (1989) were two of the first researchers to explore the contribution of orthographic functioning to reading abilities. They conducted a study with 180 undergraduate students to determine how well the orthographic choice and homophone choice tasks predicted word processing abilities. One of the reading tests was a word recognition task where the participants were required to read regular words (i.e., “common orthographic pattern and frequent spelling/sound correspondence” such as “math”), exception words (i.e., “common orthographic pattern and infrequent spelling/sound correspondence” such as “steak”), and strange words (i.e., “uncommon orthographic pattern and infrequent spelling/sound correspondence” such as “gauge”; Stanovich & West, 1989, p. 416). They revealed that the composite of orthographic functioning tasks accounted for unique variance in the word reading composite after controlling phonological processing.

Subsequent research has supported the contribution of orthographic functioning to reading ability. Berninger, Cartwright, Yates, Swanson, and Abbott (1994) found that various measures of orthographic functioning were related to identification of both real words and nonwords, even when controlling phonological processing. These measures included the

CPST, the homophone choice test, and the orthographic choice test. Barker, Torgesen, and Wagner (1992) revealed that when the orthographic choice and homophone choice tasks were entered into a hierarchical equation as a composite after phonological processing, it predicted all five of the reading tasks. Cunningham et al. (2001) administered a battery of phonological and orthographic functioning tests to a group of children in first grade and tracked their progress until third grade. They determined that, even after variance attributed to a first grade pseudoword reading score and a phonological processing composite was partialled out, an orthographic functioning composite score predicted significant variance in third grade word recognition scores. Hence, it appears that orthographic functioning is an important contributor to reading abilities and that it is at least partially independent of phonological processing ability.

Predictors of Orthographic Functioning

Rapid Naming

There has been increasingly more attention given to the role of rapid naming abilities in orthographic functioning and reading over the past decade. Bowers, Golden, Kennedy, and Young (1994) first proposed that rapid naming abilities are related to variability in orthographic functioning, even when controlling phonological processing skills. They reported that rapid naming abilities, as measured by the rapid automatized naming (RAN)-Digits test, are significantly correlated with an untimed letter-cluster coding task. Given the high degree of correlation between rapid digit and letter naming (Bowers, 1995), they suggested that children who have difficulty retrieving letters from long-term memory may not be able to pair the sounds of the letters quickly enough in time to be responsive to typical letter patterns that are found in the English language (Adams, 1990). Thus, they may have more difficulty encoding letter-strings than children who able to rapidly identify letters.

Subsequent research has supported a role for rapid naming in orthographic functioning. For example, Manis, Doi, and Bhadha (2000) found that both RAN-Letters and -Digits accounted for unique significant variance in an orthographic composite score after controlling vocabulary knowledge and phonological processing. When assessing the double deficit theory of dyslexia, Sunseth and Bowers (2002) found that children with a rapid naming deficit performed significantly worse on two versions of the word-likeness test than children with intact rapid naming and phonological awareness. However, there were no differences on the homophone choice test between these two groups. Nonetheless, in an earlier study, Bowers, Sunseth, and Golden (1999) compared children with a phonological awareness deficit to children with a rapid naming deficit on two measures of orthographic functioning. They reported that children with the rapid naming deficit performed significantly worse and slower on the homophone choice task and a word likeness test than children with the phonological awareness deficit. As a whole, research suggests that rapid naming abilities may play an important role in orthographic functioning as assessed by word-likeness, homophone choice, and exception word tasks.

Print Exposure

Stanovich and West (1989) conducted one of the first studies to examine whether print exposure predicts orthographic functioning. They found that exposure to print was a significant predictor of the orthographic choice and homophone choice tasks after phonological processing was controlled. As an explanation for this finding, Gough, Juel, and Griffith (1992) suggested that those who have extensive practice in reading are better able to identify irregular words than those who spend less time reading. Some of the most common measures of print exposure include the Author Recognition Test (ART; Stanovich & West, 1989), Magazine Recognition Test (MRT; Stanovich & West, 1989), and the Title Recognition Test (TRT; Cunningham & Stanovich, 1990; McDowell, Schumm, & Vaughn, 1993).

Subsequent research by Cunningham and Stanovich (1998) revealed that the TRT, when entered into a hierarchical regression after measures of phonological processing, accounted for significant additional variance on an experimental spelling task and the spelling subtest from the Stanford Achievement Test. Both spelling tests were assumed to require substantial amounts of orthographic functioning due to their high correlations with other orthographic measures. However, the TRT was not predictive of a word-likeness task when controlling phonological processing. Additional research by Cunningham et al. (2001) indicated that the TRT predicted unique variance in an orthographic functioning composite after controlling phonological processing and pseudoword reading ability. Chateau and Jared (2000) found that individuals who have higher levels of print exposure as measured by the ART were quicker and more accurate in identifying homophones than those with lower levels of exposure to print. Taken together, this research suggests that exposure to print is an important predictor of orthographic functioning as measured by orthographic choice and homophone choice tasks and various spelling tasks.

Visual Processing

As there is controversy over whether visual processing is important for reading ability, research related to reading is described first before that related to orthographic functioning specifically. Boder (1973) posited that there are two distinct components to reading: a visual gestalt and an auditory analytic. The visual gestalt function is important for sight reading and uses the processes of visual perception and visual short-term memory. In contrast, the auditory analytic function overlaps with today's notion of phonological processing and decoding. Thus, according to Boder, visual perception and visual short-term memory skills may contribute to the ability to identify words when using a whole-word approach. Consistent with this notion, Eden, Stein, Wood, and Wood, (1995) found that children with a reading disabilities performed worse on measures of fixation control (i.e., vertical eye tracking and eye movement recording), divergent eye control (i.e., eye movement recording), and global depth perception than controls. Later research by Chase (1996); Eden, Stein, Wood, and Wood (1996); Valdois, Bosse, and Tainturier, (2004); and Wilmer, Richardson, Chen, and Stein, (2004) also found a link between visual processing and reading ability. Nonetheless, multiple researchers have de-emphasized the importance of visual processing to reading ability (Frost, 1998; Stanovich, 1986). Furthermore, researchers have asserted that a deficit in phonological processing is the most probable cause of reading problems rather than poor visual processing in their reviews (Stanovich, 1985; Vellutino, 1979; Vellutino et al., 2004).

Some researchers have found a link between visual processing skills and orthographic functioning. Corcos and Willows (1993) found that several visual processing indicators (e.g., Visual Discrimination and Visual Memory subtests from the Test of Visual-Perceptive Skills, Raven's Progressive Matrices, Bender-Gestalt) were significant predictors of an orthographic task that required participants to read a letter cluster (target-item) and then decide whether the next letter cluster (test-item) was the same or different from the previous one, similar to the CPST. Similarly, Stein and Talcott (1999) posited that that visual processing is an important component of orthographic functioning because it is necessary for identifying relative letter positions within words (Cornelissen & Hansen, 1998). Subsequent research has found that rapid visual processing is predictive of performance on a homophone choice task (Talcott et al. 2002) and an exception word test (Booth Perfetti, MacWhinney, & Hunt, 2000) when controlling for age and IQ. In addition, Au and Lovegrove (2006) found that parvocellular system (i.e., the part of the visual system sensitive to highly-detailed material) has greater involvement in identifying irregular words as opposed to phonetically regular words. Nonetheless, others suggest that visual processing only marginally affects orthographic learning (Share, 1999) and that phonological recoding is what is critical to orthographic development (Bowey & Muller, 2005; De Jong, Bitter, Van Setten, & Marinus, 2009; Kyte & Johnson, 2006). Thus, research remains disparate over the extent to which visual processing contributes to orthographic functioning.

Hypotheses

The purpose of this study was to examine the relative contributions of rapid automatic naming, exposure to print, and visual processing to orthographic functioning in a heterogeneous sample of 8- to 12-year-old children when controlling phonological awareness and vocabulary knowledge. Since previous research has indicated that exposure to print and rapid automatic naming abilities are predictive of orthographic functioning when examined separately, we hypothesized that both skills would predict orthographic functioning when compared. Although some researchers have concluded that visual processing does not substantially contribute to orthographic functioning (Share, 1999) or reading ability (Stanovich, 1985; Vellutino, 1979; Vellutino et al., 2004), it was examined given the work by Corcos and Willows (1993) and Eden et al., (1995) who suggested that visual processing is affected in some children with reading disorders and is important for orthographic functioning.

Method

Participants

Participants included 158 children, ages 8-12 years, who were recruited from rural communities in Southern Illinois and Eastern Washington. There were 69 females and 89 males. The ethnic background of the sample included 88% Caucasian, 7% African American, 3% Asian American, and 2% Hispanic students. All participants were fluent in English. Participants ranged in grade level from first to seventh grade and were of predominately middle class income. Diagnostic breakdown included specific learning disability in reading (RD, n = 34), Attention-Deficit/Hyperactivity Disorder (AD/HD, n = 49), co-morbid RD and AD/HD (n = 8), language deficits without dyslexia (n = 12), and typically-developing controls (n = 55). Children who were not fluent in English or had a psychiatric disorder (e.g., Generalized Anxiety Disorder, Major Depressive Disorder), neurological disorder (e.g., traumatic brain injury, epilepsy), or substantial perinatal complications (significant prematurity, hypoxia) were excluded from the study.

Children were diagnosed with RD if they had a significant discrepancy between their measured intelligence as assessed by the Weschler Intelligence Scale for Children, Third Edition (WISC-III; Weschler, 1991) from 2002-2005 or Fourth Edition (WISC-IV; Weschler, 2003) post-2005 and their Basic Reading Composite on the Woodcock Johnson-III Tests of Achievement (WJ-III; Woodcock, McGrew, & Mather, 2001). Participants completed all measures on the same day of testing, including IQ and academic achievement measures. The entire WISC was administered in order to determine IQ. Children's IQ and achievement scores were entered into a regression-based equation to determine the discrepancy needed based on the correlation between the WISC and WJ-III and the normal distribution of means. If a child's achievement score was below where it was expected based on the formula, then he or she was diagnosed with RD (e.g., the discrepancy required was 19 points for an IQ of 100). Only one participant with RD had a standard score greater than 90 on both WJ-III Letter-Word Identification and Word Attack subtests (SSs = 91 and 93, respectively). Although use of a discrepancy definition is under substantial debate, it was the accepted means of diagnosis for a Specific Learning Disability in reading when data collection began. See Table 1 for descriptive data on participants by diagnostic groups.

A multi-component approach was used to diagnose AD/HD. Parents of children participating in the study completed a questionnaire to assess the number of symptoms, settings, and age of onset using DSM-IV AD/HD diagnostic criteria (APA, 2000). In addition, the Behavior Assessment System for Children, Second Edition (BASC-2, Reynolds & Kamphaus, 2004) was used to confirm that children suspected to have AD/HD had difficulty with inattention and/or hyperactivity/impulsivity in multiple settings. Children were diagnosed with AD/HD, Predominantly Inattentive when they met DSM-IV criteria for the disorder *and* parents/teachers reported on the BASC-2 that the children had a standard score greater than 59 (i.e., 1 *SD* > mean) on the Attention Problems subscale. They were diagnosed with Combined type when they met DSM-IV criteria and had elevations on Attention Problems and Hyperactivity subscales.

Typically-developing controls did not meet criteria for RD and/or AD/HD and did not have language-based impairments. In order to rule out poor readers in the control group who would not be classified as RD under the discrepancy criteria, controls were required to have standard scores greater than 85 on each of the following subtests: WJ-III Letter-Word Identification, Word Attack, and Passage Comprehension. There were 5 control participants whose reading scores overlapped with those with RD, but these individuals did not have a substantial IQ-reading discrepancy and their reading ability was in the Average range.

Children who did not meet criteria for RD but still had language difficulties were labeled as having language deficits. These children had difficulty on the Sentence Comprehension and/or Syntax Construction subtests from the Comprehensive Assessment of the Spoken Language (CASL: Carrow-Woolfolk, 1999). As a group, children with language deficits had mean standard scores of 94 and 89, respectively, on the Sentence Comprehension and Syntax Construction subtests. In addition, they frequently struggled with measures requiring expressive language such as WISC Vocabulary.

Procedure

Each participant was administered a neuropsychological battery of tests at a grant-funded university-based laboratory. The measures were selected in order to test various theories of RD and AD/HD. This study used a subset of measures from the larger project that was collected over a 6-year period from 2002-2009. All participants were included provided they met the inclusion and exclusion criteria detailed above. Parental informed consent and child informed assent were obtained before testing began.

Measures

Vocabulary—The WISC-III/IV Vocabulary subtest was used to assess vocabulary knowledge because it has been found to be related to orthographic functioning (Manis et al., 2000; Manis, Seidenberg, & Doi, 1999; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997). Currently research suggests rapid naming and exposure to print are important predictors of orthographic functioning. To better test their unique contributions we believed that it was important to control for vocabulary knowledge given that the dual route and connectionist models suggest that orthographic and semantic functioning are tightly linked (Morton, 1969; Seidenberg & McClelland, 1989). Moreover, WISC Vocabulary has a large correlation with WISC Full Scale IQ (r = .83), so by controlling it we also were able to minimize the effects of IQ differences between groups. On this task children were instructed to provide oral definitions to increasingly more difficult words that the examiner read aloud. The raw score was converted to a standard score using the test's age-norms. The internal consistency of Vocabulary for children ages 8-12 ranges from .86 to .91.

Phonological Awareness—The Elision subtest of the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rahotte, 1999) was used as a measure of phonological awareness. This test required children to repeat a word pronounced by the examiner, and then say it again after removing a specified syllable or phoneme and blending the remaining segments together. Hence, it requires both analysis and synthesis of phonemes. The raw score was converted to a standard score using the test's age-norms. The internal consistency of Elision for children ages 8-12 ranges from .86 to .91. The WJ-III Word Attack subtest was used as second measure sensitive to phonological awareness. Children were instructed to decode a series of increasingly more difficult nonsense words. The raw score was converted to a standard score using the test's age-norms. The internal consistency of Word Attack for children ages 8-12 ranges from .88 to .90. These measures were used as a control variables given it is generally accepted that phonological awareness is predictive of orthographic functioning (Cunningham et al., 2001; Cunningham & Stanovich, 1998; Share, 1999; Stanovich & West, 1989).

Rapid Naming—Children completed the Rapid Object Naming (RAN-Objects) and Rapid Letter Naming subtests (RAN-Letters) from the CTOPP (Wagner et al., 1999) to measure their ability to rapidly retrieve lexical/phonological information from long-term memory. To complete RAN-Objects, children were told to name six common objects (i.e., boat, pencil, star, fish, chair, and key) presented in an array of four lines of nine items as fast as they could. Similarly, RAN-Letters required children to name letters as fast as they could that were presented in an identical array. The time taken to name the objects/letters was recorded, which then was converted to a standard score using the test's age-norms. RAN-Letters was used because previous research has shown it to be a better predictor of reading and orthographic functioning than RAN-Digits (Manis et al., 2000). RAN-Objects was utilized to reduce potential confounding between the independent and dependent variables, as the letter-string orthographic task used letter strings. By using both measures, correlations between the two measures and the other IVs and DVs could be assessed to determine which is the best to use. For children ages 8-12, the alternative form reliability ranges from .72 to .79 for RAN-Objects and from .73 to .87 for RAN-Letters.

Exposure to Print—The Title Recognition Test (TRT; Cunningham & Stanovich, 1990; McDowell, Schumm, & Vaughn, 1993) was used to measure exposure to print. Children were given a list of book titles and were told that some of them were names of real books while others were titles of fictitious books. They were instructed to check off the titles that they knew were real books and not to guess. The version appropriate to their grade level was given. A score was calculated by subtracting the proportion of foils checked from the proportion of actual titles checked, yielding scores ranging from −1.0 to 1.0. For example, if a child reported knowing 10 out of the 25 real books (i.e., .40) and said that 3 of the 14 foils were real books (i.e., .21), then the child would have a score of .19. Thus, if a child received a score above 0, it means that the child checked a higher proportion of real books than fictitious books. Although there does not appear to be any published norms for this measure, raw scores for each version were converted into age-standardized scores based on the means and distribution of the control sample. The internal consistency for the younger children version is .82 (McDowell et al., 1993), and the internal consistency for the older children version is .81 (Cunningham & Stanovich, 1990).

Visual Measures—Children completed subtests from the Test of Visual-Perceptual Skills-Revised (TVPS-R; Gardner, 1996). The Visual Discrimination subtest was used as a measure of visual perception. Children were required to look at a complex geometric figure and then find it below in an array of five similar forms on the same page. The Visual Memory subtest of the TVPS-R was used to assess children's visual short-term memory for nonsense geometric figures. Children were instructed to look at a complex geometric figure for four to five seconds and then find the same form in an array of five similar forms on the next page. The Visual Sequential Memory subtest of the TVPS-R assesses children's ability to remember a series of common shapes (e.g., cross, square, triangle). Children were instructed to look at a sequence of shapes and then choose the same sequence on the next page from four similar sequences of shapes. None of the visual measures were timed. For all three TVPS-R subtests, standard scores were computed using the test's age-norms. The internal consistency of the three visual measures for children ages 8-12 ranges from .30 to .

67. Although the internal consistency of the TVPS was relatively low compared to the other measures, it is a commonly used measure of visual-perception and was used by Corcos and Willows (1993).

Measures of Orthographic Functioning—An orthographic choice test adapted from Stanovich and West (1989) was used to assess children's knowledge of homophones. Children were given a list of 25 questions, each with two possible answers that were homophones. Children were instructed to answer the question by circling the correct answer. The children's raw score was the number correct out of 25. This measure was not timed. The internal consistency is .84 (Cunningham et al. 2001). Children completed a homophone choice task adapted from the work of Olson et al. (1985) as a second measure of orthographic functioning. The measure included 78 pairs of items, each consisting of a correctly spelled word and a pseudoword with the same pronunciation. Children were instructed to circle the correctly spelled item and to complete as many of the items as possible within a three-minute period. The children's raw score was the number correct out of 78. The internal consistency of a similar, untimed version of this measure with a fewer number of paired items is .62 (Cunningham et al. 2001). The raw scores for both measures were converted into age-standardized scores based on the means and distribution of the control sample.

A letter-string task adapted from DeFries et al. (CPST; 1978) was used to measure the ability to quickly discriminate between unpronounceable letter/number strings. Children were instructed to circle one of the four strings of four letters/numbers that matched the model string. The task consisted of two parts, each containing non-pronounceable letter/number strings. Most of the strings included only letters, whereas some of the strings included letters and numbers. Children were given one minute to complete each part. An overall score was calculated by summing the total number of items correct from each part. This score was then converted into an age-standardized score based on the means and distribution of the control sample. Internal consistency of this measure is unknown. It would be inappropriate to determine the internal consistency as participants often completed a different number of items. For example, one participant may have completed 5 items in the allotted time, whereas another participant may have been able to complete 10 items within the time limit.

Results

Preliminary Analyses

A bivariate correlation was conducted to determine the relation between the variables. See Table 2. A number of significant correlations were found. First, there were moderate correlations between the visual discrimination, visual short-term memory, and visual sequential memory tasks. Second, there was a large correlation between RAN-Objects and RAN-Letters. Third, there was a large correlation between Elision and Word Attack. Fourth, there were large correlations between the three orthographic measures. Given all of the significant correlations in the expected direction, an exploratory factor analysis was conducted to further examine the relation between variables and to determine if variables measuring overlapping abilities should be combined. An exploratory factor analysis with oblique rotation revealed three factors. All three visual measures loaded on one factor. RAN-Objects and RAN-Letters loaded on a second factor, and Vocabulary, Elision, Work Attack, TRT, and the three orthographic measures all loaded on the third factor. See Table 3.

Since Visual Discrimination, Visual Memory, and Visual Sequential Memory were all moderately correlated, came from the same test and norm sample, and loaded on the same factor, these scores were combined to yield an overall visual processing factor. Similarly, RAN-Objects and RAN-Letters were combined to form a rapid naming factor, and Elision and Word Attack were combined to form a phonological awareness factor. Finally, the orthographic choice, homophone choice, and letter-string tasks were combined to yield an orthographic functioning factor. Each of these factors was then age-standardized based on the means and distribution of the control sample.

Primary Analyses

Hierarchical regression was used to test the relative contributions of rapid naming, exposure to print, and visual processing to orthographic functioning after controlling vocabulary knowledge and phonological awareness. This statistical approach was chosen over simultaneous regression in order to systematically examine how the variance explained by each variable of interest changes with the position entered while controlling for the effects of vocabulary and phonological awareness. Results are presented in Table 4. They indicate that rapid naming (2-3%), exposure to print (3-5%), and visual processing (2-4%) each contribute significant unique variance to orthographic functioning regardless of their position in the equation, even when controlling vocabulary knowledge and phonological awareness which were both significant

Discussion

Although researchers have become increasingly aware that orthographic functioning may be an important skill for reading development, less is known about the various factors that contribute to it. Thus, this study was designed to systematically compare the relative contributions of rapid automatic naming, exposure to print, and visual processing to orthographic functioning in a heterogeneous sample of 8- to 12-year-old children.

Much of the research on orthographic functioning is conducted with heterogeneous samples of school-aged children in the regular education classroom (Barker et al., 1992; Bowers, et al., 1999; Cunningham et al., 2001; Cunningham & Stanovich, 1998; Manis et al., 1999, 2000; Sunseth & Bowers, 2002). The results from our research suggests that, for a heterogeneous sample of children, exposure to print and rapid naming are predictive of orthographic functioning, even after controlling vocabulary knowledge and phonological awareness. Thus, our data is largely congruent with previous research finding that exposure to print accounted for significant unique variance in orthographic functioning beyond phonological processing (Cunningham et al., 2001; Stanovich & West, 1989). The rapid naming data also is commensurate with findings from prior research that suggest rapid automatic naming abilities are predictive of orthographic functioning when controlling for phonological processing (Bowers et al., 1994; Manis et al., 1999, 2000).

Perhaps more importantly, however, our results provide preliminary evidence that both rapid automatic naming and exposure to print contribute to orthographic functioning when a heterogeneous sample is used, even when controlling one while testing the other. Prior research has examined only one of these skills at a time, and we are among the first to show that both appear to contribute uniquely to orthographic functioning. In addition, vocabulary knowledge and phonological awareness were significant predictors of orthographic functioning, which is consistent with a large body of previous research (Barker et al., 1992; Cunningham et al., 2001; Cunningham & Stanovich, 1998; Share, 1999; Stanovich & West, 1989). Given that the dual route and connectionist models suggest that orthographic and semantic functioning are tightly linked (Morton, 1969; Seidenberg & McClelland, 1989), Vocabulary's contribution to orthographic functioning is not surprising. Hence, it appears that multiple linguistic skills contribute to orthographic functioning when a heterogeneous sample is used.

Although multiple linguistic functions appear to be important contributors to orthographic functioning as hypothesized, visual processing also may play an important role in orthographic functioning. The visual composite was a significant predictor regardless of position. Although some prior work found visual processing to be predictive of various orthographic functioning tasks (Booth et al., 2000; Talcott et al., 2002), it failed to control for phonological awareness. Furthermore, Share (1999) found that visual exposure only minimally affected orthographic learning in comparison to phonological recoding. Thus, this study's findings are especially noteworthy given that the visual composite accounted for significant unique variance in orthographic functioning even when controlling for both vocabulary knowledge and phonological awareness.

Similar to many of the studies previously cited, we chose to develop an orthographic composite from multiple measures. Although the orthographic choice and homophone choice tasks are more traditional measures of orthographic functioning, we chose to add a letter-string task as a third measure given the work of Berninger et al. (1994) who found the CPST to be significantly correlated with the homophone and orthographic choice tasks. Similarly, we found large correlations between the letter-string and the homophone choice, (r = .71), the letter-string and orthographic choice (r = .51), and the homophone choice and orthographic choice tests (r = .76) in our sample. Thus, there appears to be significant overlap between the letter-string task and the orthographic choice and homophone choice tests, which Hagiliassis, Pratt, and Johnston (2006) reported were relatively pure measures of orthographic functioning. In addition, all three orthographic measures loaded on the same factor in our factor analysis. Furthermore, there were significant moderate to large correlations between the letter-string task and WJ-III Letter Word Identification (r = .54), Word Attack (r = .50), and Passage Comprehension (r = .48) subtests, which suggest that this letter-string task is related to reading ability, at least in our sample. It should be noted that the letter-string task used in this study was based upon the CPST, rather than the one reported by Hagiliassis et al. (2006), which appears to be similar to a word-likeness task. Berninger et al. (1994) also found the CPST to be related to reading ability. The results were different when the letter-string task was not added to the orthographic functioning composite. RAN was always significant, TRT was only significant when entered before RAN and Visual (approached in other positions), and Visual was never significant.

Since rapid automatic naming is predictive of orthographic functioning, it is possible that interventions targeting these abilities may help increase a student's orthographic functioning. However, there does not appear to be very many published studies in which researchers have examined interventions aimed at increasing rapid naming abilities. In one study of first grade children, de Jong & Vrielink (2004) reported that a 10-session intervention in letter-sound naming totaling 2 to 2 ½ hours did not substantially improve rapid naming abilities. In contrast, Nelson, Benner, and Gonzalez (2005) found that kindergarten children receiving a pre-reading intervention significantly improved their rapid naming abilities from pre- to post-test. It should be noted, however, that the reading intervention was comprehensive and targeted multiple components to reading, including letter identification, sentence meanings, phonological awareness, and rapid naming. Thus, it is possible that the gains in rapid naming may have been as a result of training in one or more of the other areas. Even though existing research has not definitively concluded that rapid automatic naming abilities can readily be improved, research is necessary to examine whether improvements in orthographic functioning can be attained via training in rapid automatic naming.

Given the importance of print exposure to orthographic functioning, it appears that children with poor orthographic functioning may be able to improve these abilities by reading a variety of age-appropriate books. However, this may be particularly challenging for children with poor reading abilities. A post-hoc analysis indicated that children with RD in our study had significantly lower scores on the TRT than typically developing children ($p < .01$), which suggests that children with RD were less likely to read a variety of books. In addition, children who have poor decoding skills often read less and are exposed to reading material that is too challenging for them (Allington, 1984), which may lead to frustration and create an environment that is not conducive to reading for leisure. Furthermore, children who are poor readers are less likely to read for pleasure as they mature (Cunnigham & Stanovich, 1997). Thus, for children with reading problems, it may be necessary for educators to use additional avenues to encourage print exposure to help develop their orthographic functioning.

Similar to the rapid naming literature, no published studies were found in which researchers examined whether visual processing training improved orthographic functioning. However, a few studies using visually-based interventions generally have not resulted in substantial increases in reading ability. Woodrome and Johnson (2009) reported that an intervention with six 20 minute training sessions in letter naming and visual discrimination did not lead to significant improvements in letter naming in a group of 4- to 5-year-old children. It should be noted, however, the experimental group only included 11 children, which may have been too small to detect small to moderate size effects. In an earlier study, Biegler (1978) found that an intervention including training in visual processing (i.e., visual short-term memory and visual discrimination) and reading remediation was as effective at increasing oral reading ability as an intervention that only included reading remediation. Although existing studies do not strongly suggest that visually-based trainings aid in reading development, more research is need to more fully explore the connection between visual processing and orthographic functioning, especially in terms of interventions.

Limitations and Future Directions

There are several limitations to this study that should be addressed in future research. First, there were a disproportionately large number of children with AD/HD or RD in the sample. Approximately 31% of the children were diagnosed with AD/HD and 22% were diagnosed with RD, which is larger than would be expected in a typical classroom. It is possible that since there were so many children with AD/HD or RD in the sample the results may have been differentially affected in some manner. For example, although phonological awareness appears to be preserved in children with AD/HD, rapid automatic naming may be affected (Hinshaw, Carte, Fan, Jassy, & Owens, 2007; Rucklidge, 2006). Phonological awareness, rapid naming, and vocabulary knowledge are commonly affected in RD. Second, there was not sufficient power to determine if there are differences in predictor strength between sub-groups (i.e., RD, ADHD, typically-developing readers). Future research using a larger sample size is indicated to determine whether predictors of orthographic functioning are different between these groups. Third, as this study only compared three theories of orthographic functioning, future research should extend this work by comparing additional theories, such as Share's (1995) self-teaching hypothesis.

Fourth, there may have been a potential confound between RAN measures and the dependent variable as the RAN measures and some of the tasks comprising the orthographic functioning variable are timed measures. To control for this problem, future researchers should use orthographic measures that are untimed when examining the relation between rapid automatic naming and orthographic functioning. In addition, the letter-string orthographic task used letter strings similar to RAN-Letters, which is one of the variables comprising the RAN factor. However, all of the variables were still significant regardless of position in the model even when using RAN-Objects as the measure of rapid automatic naming. Fifth, the TVPS-R Visual Discrimination, Visual Memory, and Visual Sequential Memory subtests each have poor to fair internal consistency, which may have affected the reliability of the visual processing factor. Nevertheless, the visual composite was still predictive of orthographic functioning despite the poor psychometric properties. Future research should use additional measures of visual processing that have better psychometric properties.

In conclusion, this study is among the first to directly compare multiple predictors of orthographic functioning and indicates that rapid automatic naming, exposure to print, and visual processing, along with vocabulary knowledge and phonological awareness, are significant predictors of orthographic functioning when using a heterogeneous sample. Future researchers should examine subgroups along with large heterogeneous samples longitudinally to determine if predictors vary with reading ability. For controls, TRT approached significance in all positions but RAN and Visual were not significant in any position. For RD and RD/ADHD, Visual was significant in all positions, but RAN and TRT were not significant in any position.

Acknowledgments

Funding by the National Institute of Child Health and Human Development, National Institutes of Health helped support data collection for this project (R03HD048752). This manuscript represents the findings and opinions of the authors and does not necessarily reflect the views of NIH or the Eunice Kennedy Shriver National Institute of Child Health and Human Development.

References

Adams, MJ. Beginning to read: Thinking and learning about print. MIT Press; Cambridge, MA: 1990.

Allington RL. Content coverage and contextual reading in reading groups. Journal of Reading Behavior. 1984; 16:85–96.

American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 4th ed.. Author; Washington, DC: 2000. Text Revision

Au A, Lovegrove W. Rapid visual processing by college students in reading irregular words and phonologically regular pseudowords presented singly and in contiguity. Annals of Dyslexia. 2006; 56:335–360. [PubMed: 17849204]

Barker TA, Torgesen JK, Wagner RK. The role of orthographic processing skills on five different reading tasks. Reading Research Quarterly. 1992; 27:334–345.

Berninger, V., editor. Varieties of orthographic knowledge: Theoretical and developmental issues (Vol 1). Kluwer Academic; Dordrecht, Netherlands: 1994.

Berninger VW, Cartwright AC, Yates CM, Swanson HL, Abbott RD. Developmental skills related to writing and reading acquisition in the intermediate grades: Shared and unique functional systems. Reading and Writing: An Interdisciplinary Journal. 1994; 6:161–196.

Bieger E. Effectiveness of visual training of letters and words on reading skills of non-readers. Journal of Educational Research. 1978; 71:157–161.

Boder E. Developmental dyslexia: A diagnostic approach based on three atypical reading-spelling patterns. Developmental Medicine & Child Neurology. 1973; 15:663–687.

Booth JR, Perfetti CA, MacWhinney B, Hunt SB. The association of rapid temporal perception with orthographic and phonological processing in children and adults with reading impairment. Scientific Studies of Reading. 2000; 4:101–132.

Bowers PG. Tracing symbol naming speed's unique contribution to reading disabilities over time. Reading and Writing: An Interdisciplinary Journal. 1995; 7:189–216.

Bowers, P.; Golden, J.; Kennedy, A.; Young, A. Limits upon orthographic knowledge due to processes indexed by naming speed.. In: Berninger, VW., editor. The varieties of orthographic knowledge I: Theoretical and developmental issues. Kluwer Academic Publishers; Dordtecht, Netherlands: 1994. p. 173-218.

Bowers PG, Sunseth K, Golden J. The route between rapid naming and reading progress. Scientific Studies of Reading. 1999; 3:31–53.

Bowey JA, Muller D. Phonological recoding and rapid orthographic learning in third-graders' silent reading: A critical test of the self-teaching hypothesis. Journal of Experimental Child Psychology. 2005; 92:203–219. [PubMed: 16095604]

Carrow-Woolfolk, E. Comprehensive Assessment of Spoken Language. American Guidance Service, Inc.; Circle Pines, MN: 1999.

Chase, CH. A visual deficit model in developmental dyslexia.. In: Chase, CH.; Rosen, GD.; Sherman, GF., editors. Developmental dyslexia: Neural, cognitive, and genetic Mechanisms. York Press; Timonium, MD: 1996. p. 127-156.

Chateau D, Jared D. Exposure to print and word recognition processes. Memory & Cognition. 2000; 28:143–153.

Cornelissen PL, Hansen PC. Motion detection, letter position encoding, and single word reading. Annals of Dyslexia. 1998; 48:155–188.

Corcos, E.; Willows, DM. The role of visual processing in good and poor readers' utilization of orthographic information in letter strings.. In: Wright, SF.; Groner, R., editors. Facets of dyslexia and its remediation: Studies in visual processing. 3rd ed.. North-Holland; Amsterdam: 1993. p. 95-106.

Cunningham AE, Perry KE, Stanovich KE. Converging evidence for the concept of orthographic processing. Reading and Writing: An Interdisciplinary Journal. 2001; 14:549–568.

Cunningham AE, Stanovich KE. Assessing print exposure and orthographic skills in children: A quick measure of reading experience. Journal of Educational Psychology. 1990; 82:733–740.

Cunningham AE, Stanovich KE. Early reading acquisition and its relation to reading experience and ability 10 years later. Developmental Psychology. 1997; 33:934–945. [PubMed: 9383616]

Cunningham, AE.; Stanovich, KE. The impact of print exposure on word recognition.. In: Metsala, JL.; Ehri, L., editors. Word recognition in beginning literacy. Lawrence Erlbaum Associates Publishers; Mahwah, NJ: 1998. p. 235-262.

DeFries JC, Singer SM, Foch TT, Lewitter FI. Familial nature of reading disability. British Journal of Psychiatry. 1978; 132:361–367. [PubMed: 638389]

De Jong PF, Bitter DJ, Van Setten M, Marinus E. Does phonological recoding occur during silent reading, and is it necessary for orthographic learning? Journal of Experimental Child Psychology. 2009; 104:267–282. [PubMed: 19608198]

de Jong PG, Vrielink LO. Rapid automatic naming: Easy to measure, hard to improve (quickly). Annals of Dyslexia. 2004; 54:65–88. [PubMed: 15765004]

Eden GF, Stein JF, Wood MH, Wood FB. Verbal and visual problems in reading disability. Journal of Learning Disabilities. 1995; 28:272–290. [PubMed: 7775847]

Eden GF, Stein JF, Wood MH, Wood FB. Differences in visuospatial judgment in reading-disabled and normal children. Perceptual and Motor Skills. 1996; 82:155–177. [PubMed: 8668471]

Frost R. Toward a strong phonological theory of visual word recognition: True issues and false trails. Psychological Bulletin. 1998; 123:71–99. [PubMed: 9461854]

Gardner, MF. Test of Visual-Perceptual Skills-Revised (TVPS-R): Manual. Academic Therapy Publications; Novato, CA: 1996.

Gough, PB.; Juel, C.; Griffith, P. Reading, spelling, and the orthographic cipher.. In: Gough, P.; Ehri, L.; Treiman, R., editors. Reading acquisition. Erlbaum; Hillsdale: NJ: 1992. p. 35-48.

Hagiliassis N, Pratt C, Johnston M. Orthographic and phonological processes in reading. Reading and Writing. 2006; 19:235–263.

Hinshaw SP, Carte ET, Fan C, Jassy JS, Owens EB. Neuropsychological functioning of girls with Attention-Deficit/Hyperactivity Disorder followed prospectively into adolescence: Evidence for continuing deficits? Neuropsychology. 2007; 21:263–273. [PubMed: 17402826]

Kessler B, Treiman R. Is English spelling chaotic? Misconceptions concerning its irregularity. Reading Psychology. 2003; 24:267–289.

Kyte CS, Johnson CJ. The role of phonological recoding in orthographic learning. Journal of Experimental Child Psychology. 2006; 93:166–185. [PubMed: 16246358]

Manis FR, Doi LM, Bhadha B. Naming speed, phonological awareness, and orthographic knowledge in second graders. Journal of Learning Disabilities. 2000; 33:325–333. 374. [PubMed: 15493095]

Manis FR, Seidenberg MS, Doi LM. See Dick RAN: Rapid naming and the longitudinal prediction of reading subskills in first and second graders. Scientific Studies of Reading. 1999; 3:129–157.

Mann VA, Tobin P, Wilson R. Measuring phonological awareness through the invented spelling of kindergarten children. Merrill-Palmer Quarterly. 1987; 33:365–391.

McDowell JA, Schumm JS, Vaughn S. Assessing exposure to print: Development of a measure for primary children. National Reading Conference Yearbook. 1993; 42:101–107.

Morton J. The interaction of information in word recognition. Psychological Review. 1969; 76:165–178.

Nelson JR, Benner GJ, Gonzalez J. An investigation of the effects of a prereading intervention on the early literacy skills of children at risk of emotional disturbance and reading problems. Journal of Emotional and Behavioral Disorders. 2005; 13:3–12.

Olson, RK.; Kliegl, R.; Davidson, B.; Foltz, G. Individual and developmental differences in reading disability.. In: Waller, T., editor. Reading research: Advances in theory and practice. Vol. 4. Academic Press; London: 1985. p. 1-64.

Olson, R.; Forsberg, H.; Wise, B.; Rack, J. Measurement of word recognition, orthographic, and phonological skills.. In: Lyon, GR., editor. Frames of reference for the assessment of learning disabilities: New views on measurement issues. Paul H. Brookes Publishing Co.; Baltimore, MD: 1994. p. 243-277.

Reynolds, CR.; Kamphaus, RW. Behavior Assessment System for Children-Second Edition (BASC-2). AGS Assessments; Circle Pines, MN: 2004.

Rucklidge JJ. Gender differences in neuropsychological functioning of New Zealand adolescents with and without attention deficit hyperactivity disorder. International Journal of Disability, Development and Education. 2006; 53:47–66.

Seidenberg MS, McClellan JL. A distributed, developmental model of visual word recognition and naming. Psychological Review. 1989; 96:523–568.

Share DL. Phonological recording and self-teaching: Sine qua non of reading acquisition. Cognition. 1995; 55:151–218. [PubMed: 7789090]

Share DL. Phonological recoding and orthographic learning: A direct test of the self teaching hypothesis. Journal of Experimental Child Psychology. 1999; 72:95–129. [PubMed: 9927525]

Snowling MJ. Phonological processing and developmental dyslexia. Journal of Research in Reading. 1995; 18:132–138.

Stanovich KE. Explaining the variance in reading ability in terms of psychological processes: What have we learned? Annals of Dyslexia. 1985; 35:67–96. [PubMed: 24243410]

Stanovich KE. Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. Reading Research Quarterly. 1986; 21:360–407.

Stanovich KE, Siegel LS. The phenotypic performance profile of reading-disabled children: A regression-based test of the phonological-core variable-difference model. Journal of Educational Psychology. 1994; 86:24–53.

Stanovich KE, West RF. Exposure to print and orthographic processing. Reading Research Quarterly. 1989; 24:402–433.

Stein J, Talcott J. Impaired neuronal timing in developmental dyslexia—The magnocellular hypothesis. Dyslexia. 1999; 5:59–77.

Sunseth K, Bowers PG. Rapid naming and phonemic awareness: Contributions to reading, spelling, and orthographic knowledge. Scientific Studies of Reading. 2002; 6:401–429.

Talcott JB, Witton C, Hebb GS, Stoodley CJ, Westwood EA, France SJ, et al. On the relationship between dynamic visual auditory processing and literacy skills: Results from a large primary-school study. Dyslexia. 2002; 8:204–225. [PubMed: 12455851]

Torgesen JK, Wagner RK, Rashotte CA, Burgess S, Hecht S. Contributions of phonological awareness and rapid automatic naming ability to the growth of word reading skills in second- to fifth-grade children. Scientific Studies of Reading. 1997; 1:161–185.

Treiman, R. Beginning to spell: A study of first grade children. Oxford University Press; New York: 1993.

Valdois S, Bosse M, Tainturier M. The cognitive deficits responsible for developmental dyslexia: Review of evidence for a selective visual attentional disorder. Dyslexia: An International Journal of Research and Practice. 2004; 10:339–363.

Vellutino, FR. Dyslexia: Theory and research. MIT Press; Boston, MA: 1979.

Vellutino FR, Fletcher JM, Snowling MJ, Scanlon DM. Specific reading disability (dyslexia): What have we learned in the past four decades? Journal of Child Psychology and Psychiatry. 2004; 45:2–40. [PubMed: 14959801]

Wagner RK, Torgesen JK. The nature of phonological processing and its causal role in the acquisition of reading skills. Psychological Bulletin. 1987; 101:192–212.

Wagner, RK.; Torgesen, JK.; Rahotte, CA. Examiner's manual: The Comprehensive Test of Phonological Processing. Pro-ed; Austin, TX: 1999.

Weschler, D. Manual for the Weschler Intelligence Scale for Children-Third Edition (WISC-III). The Psychological Corporation; San Antonio, TX: 1991.

Weschler, D. Weschler Intelligence Scale for Children-Fourth Edition (WISC-IV) administration ad scoring manual. The Psychological Corporation; San Antonio, TX: 2003.

Wilmer JB, Richardson AJ, Chen Y, Stein JF. Two visual motion processing deficits in developmental dyslexia associated with different reading skills deficits. Journal of Cognitive Neuroscience. 2004; 16:528–540. [PubMed: 15165346]

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Woodcock, RW. Examiner's manual: Woodcock Reading Mastery Tests-Revised. American Guidance Service; Circle Pines, MN: 1987.

Woodrome SE, Johnson KE. The role of visual discrimination in the learning-to read process. Reading & Writing. 2009; 22:117–131.

Table 1

Participant Descriptive Information

	Controls *M SD*	RD *M SD*	RD/ADHD *M SD*	ADHD *M SD*	Other *M SD*
Age	10.53 (1.54)	9.93 (1.43)	9.44 (1.31)	10.15 (1.37)	10.22 (1.47)
WISC-III/IV					
FSIQ	103.58 (13.05)[abcd]	91.35 (13.89)	92.13 (13.54)	94.12 (14.25)	91.50 (14.28)
WJ-III					
LWI	105.36 (11.32)[abd]	77.67 (7.58)	79.75 (8.70)	102.41 (12.46)[fh]	94.50 (9.97)[gij]
WA	103.20 (9.78)[abd]	86.44 (6.01)	85.25 (10.53)	102.77 (10.79)[fh]	96.33 (6.80)[gij]
PC	103.06 (9.96)[abcd]	81.09 (11.49)	81.75 (9.59)	94.67 (9.54)[fh]	90.83 (9.11)[g]
Spell	101.33 (14.74)[abd]	75.15 (10.51)	75.25 (11.49)	97.22 (15.64)[fh]	89.42 (7.20)[gi]
CTOPP					
Elision	100.73 (15.41)[abd]	83.09 (11.81)	89.38 (10.84)	96.02 (14.93)[f]	83.18 (15.37)[j]
RAN-L	95.91 (11.14)[ab]	84.85 (12.82)	83.75 (8.34)	97.60 (12.72)[fh]	90.50 (9.26)
RAN-O	90.64 (13.68)[ab]	80.46 (13.54)	72.50 (14.39)	86.70 (15.89)[h]	91.81 (13.65)[gi]
BASC-II					
P Att.	48.31 (10.73)[abcd]	55.12 (8.17)[e]	70.50 (6.49)	67.78 (6.20)[f]	59.82 (8.56)[ij]
T Att.	46.84 (9.61)[abc]	56.10 (6.99)[e]	64.63 (10.14)	61.34(10.21)[f]	52.50 (11.76)[ij]
P Hyp.	45.23 (10.45)[bcd]	46.27 (8.27)[e]	55.25 (10.78)	59.20 (12.82)[f]	54.45(9.71)[g]
T Hyp.	45.55 (7.35)[bc]	49.94 (8.06)	56.00 (9.61)	58.27 (13.16)[f]	49.50 (8.55)[j]

Note: WISC-III/IV = Weschler Intelligence Scale for Children, Third or Fourth Edition; FSIQ = Full Scale IQ; WJ-III = Woodcock-Johnson III Tests of Achievement; LWI = Letter Word Identification, WA = Word Attack; PC = Passage Comprehension; Spell = Spelling; CTOPP = Comprehensive Test of Phonological Processing; RAN-L = Rapid Automatized Naming-Letters; RAN-O = Rapid Automatized Naming-Objects; BASC-II = Behavior Assessment System for Children, Second Edition; P Att = Parent-rated Attention Problems; T Att = Teacher-rated Attention Problems; P Hyp = Parent-rated Hyperactivity; T Hyp = Teacher-rated Hyperactivity. Each subscript indicates where there is a significant difference between two groups at the .05 level.

[a]Control and RD

[b]Control and RD/ADHD

[c]Control and ADHD

[d]Control and Other

[e]RD and RD/ADHD

[f]RD and ADHD

[g]RD and Other

[h]RD/ADHD and ADHD

[i]RD /ADHD and Other

[j]ADHD and Other

Table 2

Bivariate Correlations

	Voc	Elision	WA	RAN-L	RAN-O	TRT	VDis	VMem	VSeq	OC	HO	CPST
Voc	---	.380**	.417**	.070	.005	.326**	.283**	.294**	.292**	.302**	.297**	.285**
Elision		---	.627**	.235**	.163*	.298**	.240*	.299**	.345**	.464**	.491**	.469**
WA			---	.403**	.251**	.283**	.263**	.251**	.404**	.595**	.596**	.495**
RAN-L				---	.684**	.209*	.148	.105	.264**	.254**	.356**	.350**
RAN-O					---	.201*	.173*	.209*	.298**	.248**	.410**	.402**
TRT						---	.172*	.119	.247*	.293**	.315**	.397**
VDis							---	.585**	.403**	.129*	.147**	.302**
VMem								---	.494**	.267*	.255**	.343**
VSeq									---	.308**	.311**	.267**
OC										---	.755**	.509**
HC											---	.704**
CPST												---

Note: Voc = Vocabulary; WA = Word Attack; RAN-L = Rapid Automatized Naming-Letters; RAN-O = Rapid Automatized Naming-Objects; TRT = Title Recognition Test; VDisc = Visual Discrimination; VMem = Visual Memory; VSeq = Visual Sequential Memory; OC = Orthographic Choice; HC = Homophone Choice; CPST = Colorado Perceptual Speed Test.

* $p < .05$

** $p < .01$

NIH-PA Author Manuscript
NIH-PA Author Manuscript

Table 3

Exploratory Factor Analysis Factor Loadings

	1	2	3
Voc	.507	.438	.314
Elision	.785	.190	.155
WA	.743	.242	.021
TRT	.491	.175	.025
RAN-L	.281	.041	.801
RAN-O	.097	.218	.856
VDis	.073	.825	.051
VMem	.315	.601	.204
VSeq	.151	.850	.129
OC	.806	.035	.128
HC	.821	.027	.314
CPST	.612	.199	.317

Note: Voc = Vocabulary; WA = Word Attack; TRT = Title Recognition Test; RAN-L = Rapid Automatized Naming-Letters; RAN-O = Rapid Automatized Naming-Objects: VDis = Visual Discrimination; VMem = Visual Memory; VSeq = Visual Sequential Memory; OC = Orthographic Choice; HC = Homophone Choice; CPST = Colorado Perceptual Speed Test

Table 4

Hierarchical Regressions Predicting Orthographic Functioning

Variable	R^2	Adj R^2	R^2 Change	*p*
Step 1				
Vocabulary	.098	.092	.098	.001
Step 2				
PA	.351	.342	.253	.001
Step 3				
Visual	.388	.374	.037	.004
Step 4				
RAN	.408	.390	.020	.035
Step 5				
TRT	.440	.418	.032	.006
Step 1				
Vocabulary	.098	.092	.098	.001
Step 2				
PA	.351	.342	.253	.001
Step 3				
RAN	.383	.369	.032	.008
Step 4				
Visual	.408	.390	.025	.018
Step 5				
TRT	.440	.418	.032	.006
Step 1				
Vocabulary	.098	.092	.098	.001
Step 2				
PA	.351	.342	.253	.001
Step 3				
Visual	.388	.374	.037	.004
Step 4				
TRT	.423	.407	.035	.005
Step 5				
RAN	.440	.418	.017	.050
Step 1				
Vocabulary	.098	.092	.098	.001
Step 2				
PA	.351	.342	.253	.001
Step 3				
TRT	.397	.386	.046	.001
Step 4				
Visual	.423	.407	.026	.015

Variable	R^2	Adj R^2	R^2 Change	*p*
Step 5				
RAN	.440	.418	.017	.050
Step 1				
Vocabulary	.098	.092	.098	.001
Step 2				
PA	.351	.342	.253	.001
Step 3				
TRT	.397	.386	.046	.001
Step 4				
RAN	.422	.405	.025	.020
Step 5				
Visual	.440	.418	.018	.044
Step 1				
Vocabulary	.098	.092	.098	.001
Step 2				
PA	.351	.342	.253	.001
Step 3				
RAN	.383	.369	.032	.008
Step 4				
TRT	.422	.405	.039	.003
Step 5				
Visual	.440	.418	.018	.044

Note: PA = Phonological Awareness, RAN = Rapid Automatized Naming, TRT = Title Recognition Test