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THE CONTRIBUTION OF EXECUTIVE SKILLS TO READING COMPREHENSION

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Abstract

Although word recognition deficits (WRD) are a known cause of reading comprehension deficits (RCD), other contributions to RCD, including executive function (EF), have not been fully explored. We examined the contribution of EF (working memory and planning), along with attention, decoding, fluency, and vocabulary to reading comprehension in 60 children (including 16 WRD and 10 RCD), ages 9–15 years. After controlling for commonly accepted contributors to reading comprehension (i.e., attention, decoding skills, fluency, and vocabulary), EF continued to make a significant contribution to reading comprehension but not to word recognition skills. These findings highlight the need for consideration of the role of EF in RCD.

Keywords

Reading comprehension; Reading disability; Executive functions; Attention deficit/hyperactivity disorder

INTRODUCTION

In the past few decades, researchers have found that reading comprehension success or failure is largely determined by the ability to read single words or to decode (Adams, 1990; Lyon, 1995; Torgesen, 2000). To learn to decode, a child must be able to manipulate the sound structure of speech and to understand that words are composed of phonemes, the smallest segments of speech. Children who have difficulty learning to decode have specific deficits in phonological processing, the ability to manipulate the sound structure of language (Fletcher et al., 1998; Lyon, 1995). Without being able to understand that the letters in words are related to phonemes, children have difficulty becoming proficient decoders, which negatively impacts their reading comprehension. Many studies support the contribution of word reading to reading comprehension. To date, a large body of research has established that word reading deficits (WRD) do adversely influence reading comprehension, and there is little debate that children who have WRD will also have reading comprehension deficits (RCD) (Shankweiler, 1999; Torgesen, 2000). One apparent reason that WRD leads to RCD is that it is difficult to glean information from text without the ability to sound out words accurately, particularly for young children just learning to read. Nevertheless, RCD cannot always be attributed to WRD. Adequate reading comprehension depends on other cognitive skills beyond word decoding, including reading fluency, language comprehension, and other higher level skills, including

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those that could be included within the rubric of executive function (e.g., working memory, planning, organizing, and monitoring).

Fluency, or the ability to read words quickly and accurately either in isolation or text, is critical for reading comprehension, particularly for older children who increasingly are required to use reading as a means for learning new information. Lack of fluency increases demands on other cognitive processes such as verbal working memory and results in difficulty with comprehension. Thus, Perfetti and colleagues long have postulated that lack of fluency impedes comprehension even when accurate decoding is achieved (Perfetti & Hogaboam, 1975; Perfetti, Marron, & Foltz, 1996). Studies have shown that improvements in fluency are associated with accompanying improvements in reading comprehension (e.g., Berninger, Abbott, Vermeulen, & Fulton, 2006; Cates, Thomason, Havey, & McCormick, 2006; O'Connor, White, & Swanson, 2007). Fluency appears particularly critical for students in late elementary school, as they are making the transition from "learning to read" to "reading to learn" and moving from decoding individual words to automatic, efficient word identification (Yovanoff, Duesbery, Alonzo, & Tindal, 2005).

Another well-studied constraint on reading comprehension is oral language proficiency. If an individual has trouble understanding spoken language, it is highly unlikely that he/she will comprehend written language. Language comprehension is itself multifaceted. Knowledge and skills involving vocabulary, background information, grammatical structures, metaphorical language, and inferential reasoning must be applied in a coordinated manner to understand connected text. One large study examining the relation between oral language skills and reading comprehension found that children identified as poor readers in second grade were three to five times more likely to have a history of oral language problems in kindergarten than competent second grade readers (Catts, Fey, Zhang, & Tomblin, 1999). Kindergarten oral language skills also accounted for significant variance in second grade reading comprehension after controlling for phonological awareness and rapid naming skills (Catts et al., 1999). The relation between language deficits and reading comprehension appears relatively stable over time. Catts and colleagues found that language comprehension deficits still contributed to RCD when their sample reached the fourth grade (Catts, Hogan, & Fey, 2003). Studies of adolescent and young adult readers also have demonstrated that vocabulary knowledge plays a significant role in reading comprehension (Braze, Tabor, Shankweiler, & Mencl, 2007; Cunningham, Stanovich, & Wilson, 1990; Lundquist, 2004; Ransby & Swanson, 2003; Yovanoff et al., 2005).

After accounting for the influence of word reading accuracy, fluency, and oral language proficiency, there are other higher level cognitive processes that have been found to play a role in reading comprehension, such as working memory limitations, poor inference making, and ineffective comprehension monitoring (Williams, 2003). These processes can be conceptualized as falling within the rubric of executive functioning. Executive function is a broad term that encompasses many higher order skills necessary for independent, goal-directed behavior, including holding and manipulating information in working memory, planning/ sequencing multistep tasks, and ascertaining the "big picture" from a complicated set of details (Denckla, 1989). Children who read fluently but do not understand what they read may have problems with executive functioning.

Working memory is one aspect of executive function that has been associated with reading ability. Children with dyslexia show deficits on working memory tasks in both verbal and visual domains (Reiter, Tucha, & Lange, 2005). A cross-sectional study examining verbal working memory in children with reading disabilities relative to skilled readers ages 7 to 20 years noted that while working memory skills improved with age among the skilled readers, little age-related change was observed in children with reading disabilities, such that the difference between groups increased steadily over time (Swanson, 2003). Verbal working memory also has been linked specifically to reading comprehension, both in normal, highly experienced readers and in impaired readers (e.g., Carpenter & Just, 1988; Daneman & Carpenter, 1980; Just & Carpenter, 1992; Swanson, 1999; Swanson & Alexander, 1997; Swanson, Ashbaker, & Sasche-Lee, 1996; Swanson & Berninger, 1995; Swanson & Jerman, 2007; Swanson & Trahan, 1996). Greater working memory capacity is thought to facilitate comprehension through the availability of ample cognitive resources to simultaneously engage in multiple reading processes such as decoding unfamiliar words, retrieving semantic knowledge of familiar words, recalling previously read text, and anticipating where the passage is going.

Planning skill represents another component of executive function that appears related to reading comprehension. Successful reading comprehension is thought to depend in part upon higher level executive skills such as reasoning and critical analysis (Vellutino, Scanlon, & Lyon, 2000). Individuals with good reading comprehension are more likely to use cognitive and metacognitive strategies (Palincsar & Brown, 1984; Pearson & Fielding, 1991; Pressley, 2000; Tierney & Cunningham, 1984). In contrast, children who struggle with reading comprehension tend to perform worse than typically developing peers on measures that require planning an organized response. For example, their copies of a complex geometric figure appear less structured and organized, and they require longer planning times to complete items on a visual problem-solving task (Keeler, 1995; Reiter et al., 2005).

In summary, for many children, difficulties with reading comprehension appear to be a natural consequence of a primary deficit in word reading accuracy. However, reading comprehension problems also develop in children whose single word reading is intact. Reading fluency and oral language proficiency are well-documented contributors to reading comprehension skill. The goal of the present study was to explore whether executive functions, particularly in the areas of working memory and planning skills, represent an additional component of reading after accounting for individual differences in attention, basic decoding skills, reading fluency, and vocabulary. Specifically, we hypothesized that executive functions would be significantly associated with reading comprehension skills, but not single word reading accuracy, thereby suggesting executive function as a potential contributor to reading comprehension ability.

METHODS

Participants

Participants were recruited to enroll in a study of Reading Disabilities (RD). Study recruitment flyers were mailed to directors of learning disability organizations and clinics. Recruiting announcements also were included in learning disability organization newsletters that were mailed directly to families of children with learning disabilities. Both children with RD (WRD and/or RCD) and children with no RD between the ages of 9 and 15 years were recruited. Study participation was limited to this age group for two reasons. First, normative data for these ages were available for all instruments in the assessment battery, allowing all participants to be assessed with the same set of tests. Second, the youngest study participants were in the third grade. Prior to third grade, reading instruction emphasizes word decoding or “learning to read,” whereas the emphasis shifts to reading comprehension or “reading to learn” in later primary grades. WRD was defined as performance below the 25th percentile on a single word reading measure (Word Reading from the Wechsler Individual Achievement Test – Second Edition [WIAT-II]). RCD was defined as performance below the 25th percentile on two of three measures of reading comprehension (Reading Comprehension from the WIAT-II, Comprehension from the Gray Oral Reading Test – Fourth Edition [GORT-4], Passage Comprehension from the Woodcock Reading Mastery Test – Revised [WRMT-R]). All children participating in the study were screened by an initial telephone interview for: 1) previous diagnosis of Mental Retardation; 2) known uncorrectable visual impairment; 3) documented hearing loss of 25 decibels or more in either ear; 4) history of known neurological disorder (e.g., epilepsy, cerebral palsy); 5) treatment with psychotropic medications for any psychiatric disorder other than attention deficit/hyperactivity disorder (ADHD). Children with ADHD were included in the study because of the hypothesized relation between reading comprehension deficits and executive dysfunction in children with intact single word reading skills. Children with comorbid Oppositional Defiant Disorder (ODD) were retained in the study because, while research suggests that ADHD and comorbid Conduct Disorder may constitute a discrete subtype, similar findings have not been reported for ADHD with comorbid ODD (Biederman et al., 1992; Faraone et al., 1995). Children with all other comorbid psychiatric disorders were excluded in order to specifically examine the neuropsychological profile associated with RD.

Procedures

Potential participants initially were screened via telephone interview. Children who met all inclusion and exclusion criteria were enrolled in the study and completed the neuropsychological and reading measures. Caregivers provided written consent and child participants gave written assent to study participation prior to beginning testing. Caregivers received a written summary of their child’s performance on all neuropsychological measures approximately four to six weeks after completing testing. In order to address the research questions outlined above, a subset of standardized measures was selected that included a measure of reading comprehension as well as measures of cognitive processes thought to support reading comprehension (i.e., attention, word decoding, reading fluency, vocabulary, and executive function measures emphasizing working memory and planning). Measures were selected from different instruments in order to minimize the influence of shared method variance on correlational analyses. However, a measure of single word reading accuracy was selected from the same instrument as the measure of reading comprehension in order to determine whether the cognitive processes outlined above differentially predicted reading comprehension or equally predicted single word reading. The following selected measures are described in greater detail below: the Attention scale of the Behavioral Assessment System for Children (BASC), the Word Attack subtest from the WRMT-R, the Fluency score from the GORT-4, the Peabody Picture Vocabulary Test -Third Edition (PPVT-III), the Freedom from Distractibility Index (FDI) from the Wechsler Intelligence Scale for Children - Third Edition (WISC-III), the number of excess moves from the Tower of London, and the Reading Comprehension and Word Reading subtests from the WIAT-II.

BASC Attention Scale—The BASC is a broadband parent behavior rating scale that allows parents to report on the relative frequency of a wide variety of adaptive and maladaptive behaviors (Reynolds & Kamphaus, 1992). It was developed based on a comprehensive review of existing behavior rating instruments, consultation with numerous experienced pediatric clinicians, and solicitation of descriptions of both adaptive and problem behaviors from classroom teachers and students. Scales and items were initially developed a priori to assess a wide range of empirically validated clinical and adaptive constructs (e.g., hyperactivity, leadership). Items on the Attention Problems scale were developed to assess the extent to which a child is easily distracted and has difficulty sustaining concentration (Kamphaus et al., 1999). The BASC has been found to be a valid instrument for the diagnosis of ADHD and its subtypes (Doyle, Ostrander, Skare, Crosby, & August, 1997; Vaughn, Riccio, Hynd, & Hall, 1997).

WRMT-R Word Attack—The WRMT-R is a comprehensive battery designed to measure multiple aspects of reading, including prereading skills (e.g., letter identification), single word reading, and reading comprehension (Woodcock, 1987). The Word Attack subtest measures a child's word reading accuracy by presenting a series of pseudowords that the child must decode using phonic and structural analysis skills.

GORT-4 Fluency—The GORT-4 is a standardized measure of oral reading fluency and comprehension that requires participants to read a paragraph aloud and then to answer a series of questions based on the information they just read (Wiederholt & Bryant, 2001). The level of reading difficulty increases progressively with each consecutive paragraph. The Fluency score is a composite derived from both the speed and the accuracy of the individual's oral reading across paragraphs.

PPVT-III—Single word receptive vocabulary was assessed using the PPVT-III, a measure where participants hear a series of words spoken by the examiner and must respond to each word by pointing to the appropriate picture among a field of four black and white line drawings (Dunn & Dunn, 1997).

WISC-III FDI—The WISC-III is a standardized instrument measuring intellectual ability in children (Wechsler, 1991). It is comprised of 13 subtests that sample a wide range of both verbal and visual-spatial problem-solving abilities. Using results from maximum-likelihood factor analysis, developers of the WISC-III suggest that these sub-tests can be divided into four factors, Verbal Comprehension, Perceptual Organization, Processing Speed, and Freedom from Distractibility (FDI). The FDI factor is composed of the Arithmetic and Digit Span subtests. For both subtests, the participant must attend to verbal information presented aurally and then manipulate that information in some way, either by performing mental calculations (Arithmetic) or by repeating back progressively longer series of numbers in reverse order (the Digits Backward portion of Digit Span). As such, the FDI factor relies heavily upon verbal working memory (although demands on other skills are also present; e.g., following verbal directions, mental computation, and concentration; Sattler, 1992). Both the Digit Span subtest individually and the FDI have been used as measures of verbal working memory in children and adolescents with reading disabilities and ADHD (Mehta, Goodyer, & Sahakian, 2004; Rucklidge & Tannock, 2002).

Tower of London—The Tower of London is a visual problem-solving task commonly used to assess planning skills (Anderson, Anderson, & Lajoie, 1996; Shallice, 1982). This task requires individuals to move a set of colored disks one by one from an initial state to a goal state using the fewest number of moves possible while following prescribed rules for how the disks may be moved (e.g., larger disks may not be placed on smaller disks). Performance on this task was determined by the number of moves the child needed in excess of the most efficient solution to reach the goal state. In order to minimize administration and scoring errors, participants completed the Colorado Assessment Tests computerized version of the Tower of London (Davis & Keller, 1998). Task parameters were modified to be consistent with those used with a normative sample of 376 children ages 7 to 14 years (Anderson et al., 1996).

WIAT-II Reading Comprehension and Word Reading—The WIAT-II is a comprehensive instrument developed to assess academic achievement in reading, writing, mathematics, and oral language (The Psychological Corporation, 2001). The Reading Comprehension subtest measures the individual's understanding of passages that may be read silently or aloud, as well as short sentences that must be read aloud. Comprehension questions regarding the content of each passage pertain to the main idea, specific details, inferences that can be drawn from the passage, and the meanings of passage vocabulary words. The child is permitted to refer back to the passage while responding to the questions. The Word Reading subtest is an untimed measure of word reading accuracy (The Psychological Corporation, 2001).

Data Analyses

Hierarchical multiple regression analysis was used to examine the relative contribution of measures of attention, word decoding, reading fluency, vocabulary, working memory, and planning to the prediction of reading comprehension. The same model was applied to the prediction of scores on the Word Reading subtest from the WIAT-II in order to assess whether executive functions such as working memory and planning differentially predicted performance on measures of reading comprehension or equally predicted performance on measures of single word reading.

RESULTS

Sample Characteristics

Study participants included 60 children (30 male). Participants ranged in age from 9 to15 years (M = 11.8 years ± 1.5). Race/ethnicity was available for 40 children; of these, 30 (75%) were white and 8 (20%) were black. The remaining 2 children identified as Asian and biracial, respectively.

Within the full sample, 16 children had deficits in word reading accuracy (WRD) and 10 had deficits in reading comprehension (RCD), as defined above. The sample included 16 children who previously had been diagnosed with attention deficit/hyperactivity disorder (ADHD) and 14 children who were currently taking stimulant medication. Table 1 delineates the proportion of the sample with specific reading or attention difficulties. The comorbidity of reading and attention difficulties within this study sample is illustrated in Figure 1. In this sample, RCD occurred in the context of both WRD and ADHD, but rarely occurred in isolation.

Cognitive Predictors of Reading Comprehension

Descriptive statistics for each of the cognitive variables of interest are summarized in Table 2. Mean scores for all tasks were broadly within the expected range. Although the mean rating on the attention subscale of the BASC was above the 75th percentile, it remained in the subclinical range. Similarly, while the mean GORT-4 Fluency score was below the 25th percentile, it was within one standard deviation of the expected mean for the test.

The zero-order relations between performance on the WIAT-II Reading Comprehension subtest and performance on tasks measuring cognitive processes thought to support reading comprehension were examined using Pearson's correlation coefficient. Scores on selected measures of attention, word decoding, reading fluency, receptive vocabulary, working memory, and planning were all significantly related to performance on the WIAT-II Reading Comprehension subtest, with the absolute value of correlation coefficients ranging from $r = .41$ to $r = .68$, $p < .01$. Performance on measures of decoding skills, reading fluency, vocabulary, and working memory were positively correlated with reading comprehension, with higher scores predicting better performance on the WIAT-II Reading Comprehension subtest. Parent ratings of attention problems and excess moves on the Tower task were negatively correlated with reading comprehension, such that better reading comprehension was associated with fewer reported attention problems and fewer moves (i.e., more efficient solutions) to reach the Tower goal states.

After establishing the significant relations between each of the cognitive variables listed above and scores on the WIAT-II Reading Comprehension subtest, each variable's relative contribution to reading comprehension performance was evaluated using hierarchical multiple regression analysis. The model was constructed a priori to control first for inattention, decoding skills, reading fluency, and vocabulary, respectively. Variables measuring working memory and planning skills then were entered consecutively to evaluate each variable's unique contribution to reading comprehension. Because the majority of measures yielded standardized scores corrected by age, age at assessment was not included as a variable in the model. Although the planning measure (number of excess moves on the Tower of London) was not age corrected, performance on this task was not correlated with age. The hierarchical regression model included the following steps: 1) the Attention scale from the BASC, 2) the Word Attack subtest from the WRMT-R, 3) the Fluency score from the GORT-4, 4) the PPVT-III, 5) the Freedom from Distractibility Index from the WISC-III, and 6) the number of excess moves from the Tower of London. The dependent variable was the Reading Comprehension subtest from the WIAT-II. The overall model was related significantly to reading comprehension, $F(6, 50) = 16.76$, $p < .001$. The means, standard deviations, and intercorrelations are listed in Table 3. Table 4 lists results of the hierarchical regression analysis. After controlling for inattention and decoding skills, reading fluency (i.e., GORT-4 Fluency), vocabulary (PPVT-III), working memory (WISC-III FDI), and planning (Tower excess moves), each made a significant unique contribution to prediction of Reading Comprehension. Specifically, higher scores on measures of reading fluency, vocabulary, and working memory, and fewer excess moves on the Tower of London were associated with higher reading comprehension scores. The adjusted R^2 value was .63, signifying that 63% of the variance in performance on the WIAT-II subtest of Reading Comprehension was explained by the model, a large effect size (Cohen, 1988).

The same model was applied to the prediction of scores on the Word Reading subtest from the WIAT-II in order to assess whether measures of executive functioning were related differentially to performance on measures of reading comprehension or equally related to performance on measures of single word reading. The model also significantly predicted Word Reading scores, $F(6, 50) = 22.20$, $p < .001$. Means, standard deviations, and intercorrelations are presented in Table 5, while the regression analyses are listed in Table 6. Results of the hierarchical regression indicate that higher scores on measures of decoding skills (Word Attack), reading fluency, and vocabulary significantly contributed to the prediction of higher scores on a measure of single word reading. However, working memory and planning did not contribute significantly to the prediction of word reading scores. The adjusted R^2 for this model was .69, indicating that the model accounted for 69% of the variance in Word Reading scores.

DISCUSSION

Many children who have difficulties with reading comprehension do so because of a primary deficit in word reading accuracy. However, other children struggle to understand what they read despite having single word reading skills that generally appear intact. This study examined the unique contribution of executive functions such as working memory and planning skills to reading comprehension in a mixed clinical sample of school-age children. Specifically, we hypothesized that executive functions would account for additional variance in reading comprehension performance after controlling for individual differences in commonly accepted skills necessary for reading including attention, basic decoding skills, reading fluency, and vocabulary. Results from a hierarchical multiple regression model including all the variables listed above as well as measures of working memory and planning accounted for 63% of the variance in reading comprehension, a large effect size. Within this model, reading fluency, vocabulary, working memory, and planning skills all made significant unique contributions to the prediction of reading comprehension. The same model also accounted for 69% of the variance in single word reading. Decoding skills emerged as a significant contributor to single word reading. Reading fluency and vocabulary skills also remained significant predictors. However, executive function skills (planning and working memory) were not significant contributors to single word reading. These results indicate that executive control skills differentially support reading comprehension but are less necessary for single word reading.

We predicted that both planning and working memory skills would be associated with reading comprehension. Consistent with our prediction, verbal working memory skills (i.e., the ability to "hold" and mentally manipulate verbal information while performing some other task) and planning skills significantly contributed to reading comprehension after controlling for individual differences in attention, decoding, reading fluency, and vocabulary. Specifically, stronger performance on tasks requiring mental manipulation and more efficient planning (i.e., fewer excess moves) on the Tower of London were both associated with higher reading comprehension scores. Our findings provide additional support to previous studies that have reported a link between working memory and reading comprehension (Carpenter & Just, 1988; Daneman & Carpenter, 1980; Just & Carpenter, 1992; Swanson, 1999; Swanson & Alexander, 1997; Swanson et al., 1996; Swanson & Berninger, 1995; Swanson & Jerman, 2007; Swanson & Trahan, 1996) and suggest that this relationship is present even after accounting for attention, decoding, speed (fluency), and vocabulary skills. Our results also highlight the importance of "higher level" planning skills in predicting reading comprehension and are consistent with prior studies that reported that children with RCD may have difficulty planning an organized, structured approach when copying a complex geometric figure and may require longer planning times to complete the Tower of London (Keeler, 1995; Reiter et al., 2005). Again, the unique finding in the present study is that this relationship holds, even when accounting for more "basic" ingredient skills known to contribute to proficient reading comprehension.

Reading comprehension is inherently more complex than single word reading, with demands that go beyond basic phonological decoding and word identification and include higher order cognitive processing of meaning conveyed through sentences and paragraphs. As such, it is not surprising that executive skills are better predictors of reading comprehension than of single word reading. Working memory in particular has long been thought to play a role in reading comprehension because of the need to hold already-read text in short-term memory while attempting to extract meaning from individual sentences and paragraphs (Swanson, 1999). Baddeley (1992) highlights two components from his model of working memory as being particularly necessary for reading comprehension—the phonological or articulatory loop (a temporary storage system for brief *maintenance* of verbal information) and the central executive (which oversees active *manipulation* of information in immediate memory and retrieval of information from long-term semantic memory). Children with reading disabilities have more difficulty than skilled readers when performing tasks drawing on both the phonological loop and the central executive systems (Swanson, 1999). Models of sentence comprehension also emphasize demands for executive control, such that working memory serves to constrain understanding of sentences with more complex syntactic structure (Wingfield & Grossman, 2006). Further, using fMRI, greater activation of dorsolateral prefrontal cortex was observed during comprehension of ambiguous sentences, compared with nonambiguous sentences (Novais-Santos et al., 2007). Conversely, comprehension of sentences with high working memory demand (i.e., containing additional phrases) was associated with greater inferior parietal cortex activation, highlighting a large-scale neural network supporting comprehension tasks that recruits distinct working memory and planning resources (Novais-Santos et al.). Taken together, these observations suggest that executive control skills such as planning and working memory become more necessary as the length and complexity of written text increases.

Results from the current study have implications for designing interventions for children with RCD. Interventions that emphasize systematic phonics instruction are effective for children with a primary deficit in single word reading, and such interventions would be expected to lead to improved reading comprehension for children whose RCD stems from more basic problems with word reading. However, children whose single word reading skills are intact may require interventions that focus on applying more "executive" skills to the task of reading. For example, such children may benefit from training in the use of reading strategies such as comprehension monitoring or use of linguistic context (Clay, 1985; Pinnell, 1989; RAND Reading Study Group, 2002; Vellutino & Scanlon, 2002). Our findings also have implications for early identification of children at risk for difficulties with reading comprehension. In our sample, RCD occurred almost exclusively in the context of a primary word reading deficit or ADHD. While children who show evidence of early problems with decoding are readily identified for reading intervention, students with known executive dysfunction or a diagnosis of ADHD may not be considered at risk for difficulties with reading comprehension until their deficits become frankly apparent in the later elementary grades or beyond. Early monitoring and training in the use of reading strategies may prevent these students from experiencing more entrenched difficulties with reading comprehension later in their academic careers.

One limitation of the current study is that analyses were conducted on a relatively small sample (i.e., fewer than 100 participants). Ideally, the current model should be tested on a separate, larger sample that includes racial/ethnic and socioeconomic diversity to further determine the reliability of our results. Future research should continue to explore the differences between children whose difficulties with reading comprehension stem from a more primary deficit in single word reading and those children who experience reading comprehension problems even though their basic word reading skills are intact. Studies are needed that compare these groups directly, both in terms of their neuropsychological profile of strengths and weaknesses and in terms of their response to different types of reading interventions that target either phonological or executive approaches to reading instruction. When recruiting students with RCD but intact word reading, investigators will need to allow for a high rate of comorbidity with ADHD and/or executive dysfunction. Future studies also would benefit from measuring executive skills of interest using a variety of methods including behavioral testing, parent and teacher report, and classroom observation to create more robust composite estimates of executive skills. Relatedly, it is important to note that further exploration as to the issue of the exact kinds/ types of verbal working memory that are linked to reading comprehension is needed. For example, there are variations in the extent to which verbal working memory tasks require other higher level cognitive functions (e.g., our task had the additional requirement of knowledge of numerical operations), and the literature on how (or if) visual working memory contributes to reading comprehension is mixed (Nation, Adams, Bowyer-Crane, & Snowling, 1999; Swanson, 1999).

In conclusion, both verbal working memory and planning skills made significant contribution to reading comprehension after controlling for inattention, decoding, reading fluency, and vocabulary, suggesting that executive skills are an important factor in understanding written text. Additionally, children with RCD represent a heterogeneous group; in this sample, RCD occurred in the context of both WRD and ADHD but rarely occurred in isolation. Instruction methods designed to promote the development and/or remediation of reading comprehension skills should address executive skills as well as word reading and decoding.

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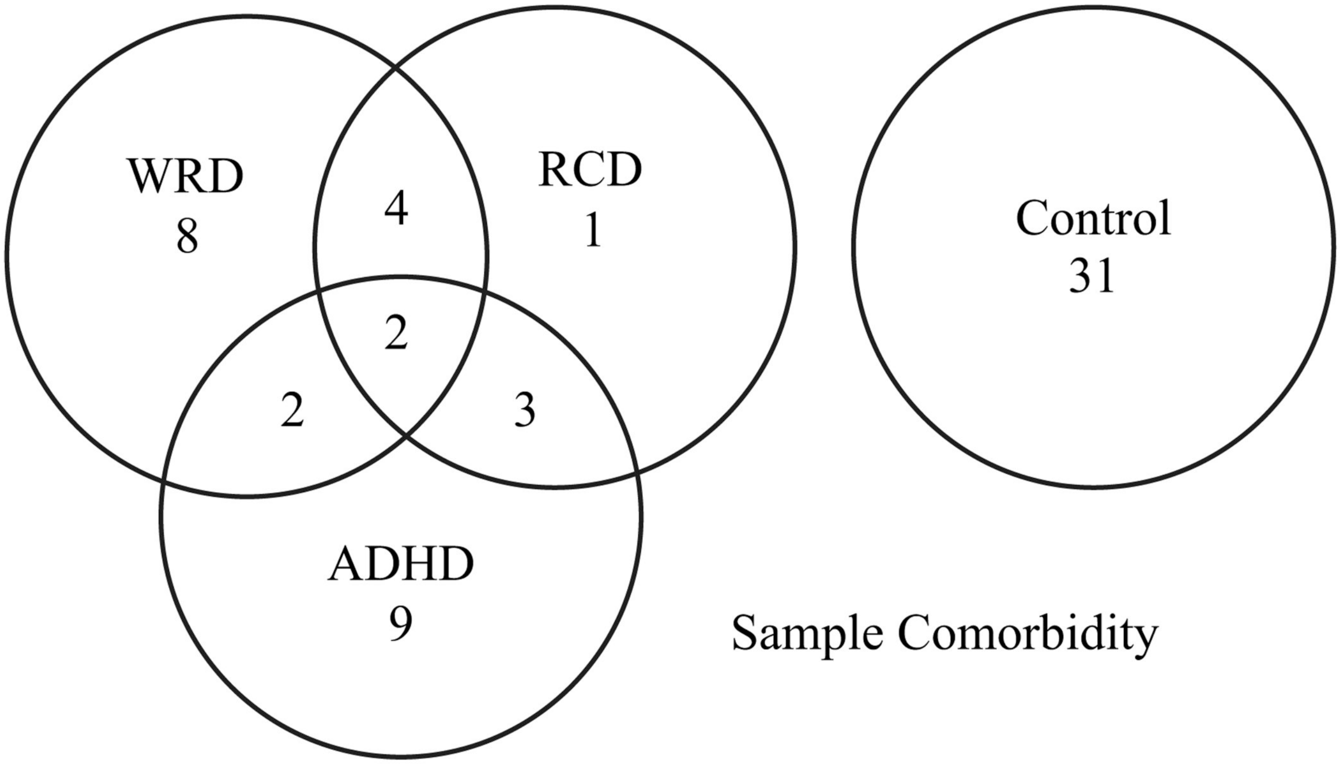

Figure 1.
The study sample was a heterogeneous group of children that included 16 with deficits in word reading accuracy (WRD), 10 with deficits in reading comprehension (RCD), and 16 who were diagnosed with ADHD. In this sample, RCD occurred in the context of both WRD and ADHD, but rarely occurred in isolation.

Table 1

Sample Characteristics (*N* = 60).

	N	**%**
Males	30	50
Word Reading Deficits (WRD)[a]	16	27
Reading Comprehension Deficits (RCD)[b]	10	17
Prior ADHD Diagnosis	16	27
Stimulant Medication	14	23
BASC Attention > 69	10	17
BASC Hyperactivity > 69	3	5

[a]WRD was defined as performance below the 25th percentile on a single word reading measure (WIAT-II Basic Word Reading).

[b]RCD was defined as performance below the 25th percentile on two of three measures of reading comprehension (WIAT-II Reading Comprehension, GORT-4 Comprehension, WRMT-R Passage Comprehension).

Table 2

Descriptive Statistics for Cognitive Variables.

	N	Mean (*SD*)
WIAT-II Reading Comprehension SS	60	101 ± 15
WIAT-II Word Reading SS	60	95 ± 15
BASC Attention T-Score	60	58 ± 12
WRMT-R Word Attack SS	59	94 ± 10
GORT-4 Fluency ScS	59	7 ± 4
PPVT-III SS	58	106 ± 14
WISC-III FDI SS	59	96 ± 14
Tower Excess Moves	58	33 ± 27

SS = Standard Score, ScS = Scaled Score.

Table 3

Means, Standard Deviations, and Intercorrelations for WIAT-II Reading Comprehension and Predictor Variables ($N = 57$).

Dependent Variable	*M*	*SD*	Predictor 1	2	3	4	5	6
WIAT-II Reading Comprehension SS	103	12	−.43***	.47***	.61***	.63***	.61***	−.47***
Predictor								
1. BASC Attention *T*-Score	58	12	–	−.36**	−.37**	−.12	−.44***	.25*
2. WRMT-R Word Attack SS	95	8		–	.59***	.27*	.37**	−.16
3. GORT-4 Fluency ScS	7	4			–	.48***	.47***	−.05
4. PPVT-III SS	107	14				–	.43***	−.33**
5. WISC-III Freedom from Distractibility Index SS	97	14					–	−.39**
6. Tower of London excess moves	33	27						–

* $p < .05$;

** $p < .01$;

*** $p < .001$.

SS = Standard Score; ScS = Scaled Score.

Table 4

Hierarchical Multiple Regression Analysis Predicting WIAT-II Reading Comprehension.

Step & Predictor	**β**	**ΔR^2**	**Δ*F***	***P***
1. BASC Attention *T*-Score	−.13	.18	12.44	.001
2. WRMT-R Word Attack SS	.08	.12	9.24	.004
3. GORT-4 Fluency ScS	.28	.13	11.82	.001
4. PPVT-III SS	.30	.16	19.93	.000
5. WISC-III Freedom from Distractibility Index SS	.17	.04	4.88	.032
6. Tower of London Excess Moves	−.25	.04	6.58	.013

Note. Adjusted R^2 at final step = .63; $F(6, 50) = 16.76$, $p < .001$.

Table 5

Means, Standard Deviations, and Intercorrelations for WIAT-II Word Reading and Predictor Variables ($N = 57$).

			Predictor					
Dependent Variable	***M***	***SD***	**1**	**2**	**3**	**4**	**5**	**6**
WIAT-II Word Reading SS	96	13	−.33**	71***	.78***	.51***	.41**	−.14
Predictor								
1. BASC Attention *T*-Score	58	12	–	−.36**	−.37**	−.12	−.44***	.25*
2. WRMT-R Word Attack SS	95	8		–	.59***	.27*	.37**	−.16
3. GORT-4 Fluency ScS	7	4			–	.48***	.47***	−.05
4. PPVT-III SS	107	14				–	.43***	−.33**
5. WISC-III Freedom from Distractibility Index SS	97	14					–	−.39**
6. Tower of London excess moves	33	27						–

* *$p < .05$;

** $p < .01$;

*** $p < .001$.

SS = Standard Score; ScS = Scaled Score.

Table 6

Hierarchical Multiple Regression Analysis Predicting WIAT-II Word Reading.

Step & Predictor	**β**	**ΔR^2**	**Δ*F***	***P***
1. BASC Attention *T*-Score	−.02	.11	6.86	.011
2. WRMT-R Word Attack SS	.39	.40	44.31	.000
3. GORT-4 Fluency ScS	.47	.19	33.20	.000
4. PPVT-III SS	.20	.03	4.95	.030
5. WISC-III Freedom from Distractibility Index SS	−.05	.00	.23	.634
6. Tower of London Excess Moves	−.00	.00	.00	.979

Note. Adjusted R^2 at final step = .69; $F(6, 50) = 22.20$, $p < .001$.