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Reading Comprehension in Children with ADHD: Cognitive Underpinnings of the Centrality Deficit

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Abstract

We examined reading comprehension in children with ADHD by assessing their ability to build a coherent mental representation that allows them to recall central and peripheral information. We compared children with ADHD (mean age 9.78) to word reading-matched controls (mean age 9.89) on their ability to retell a passage. We found that even though children with ADHD recalled more central than peripheral information, they showed their greatest deficit, relative to controls, on central information – a centrality deficit (Miller & Keenan, 2009). We explored the cognitive underpinnings of this deficit using regressions to compare how well cognitive factors (working memory, inhibition, processing speed, and IQ) predicted the ability to recall central information, after controlling for word reading ability, and whether these cognitive factors interacted with ADHD symptoms. Working memory accounted for the most unique variance. Although previous evidence for reading comprehension difficulties in children with ADHD have been mixed, this study suggests that even when word reading ability is controlled, children with ADHD have difficulty building a coherent mental representation, and this difficulty is likely related to deficits in working memory.

Attention Deficit/Hyperactivity Disorder (ADHD) is characterized by deficits in executive functioning and impulse control (Pennington, Groisser, & Welsh, 1993), and individuals with ADHD often struggle academically (Barkley, 2000). Although not considered a primary deficit, difficulties in reading and listening comprehension have been associated with ADHD and likely contribute to their academic struggles (e.g., Brock & Knapp, 1996; Flake, Lorch, & Milich, 2007; Flory et al., 2006; Lorch et al., 2004; McInnes, Humphries, Hogg-Johnson, & Tannock, 2003; Renz et al., 2003; Samuelsson, Lundberg, and Herkner, 2004; Zentall, 1988). Little is known, however, about the specific nature of these comprehension difficulties. The purposes of this paper are (1) to explore how ADHD impacts the mental model constructed while reading a passage by assessing how it impacts retention of the most central information, and (2) to examine the component cognitive skills involved in this process.

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Listening vs. Reading Comprehension

Individuals with ADHD often display comorbid word decoding deficits – difficulty identifying written words (McGrath et al., 2011; Shanahan et al., 2006; Willcutt et al., 2010). These decoding problems can hinder reading comprehension, making it difficult to determine whether comprehension problems are due to decoding difficulties, comprehension difficulties, or both. Thus, many studies have used listening rather than reading to explore deficits in comprehension associated with ADHD (e.g., Flake et al., 2007; Flory et al., 2006; Keenan, Betjemann, & Miller, 2008; Lorch et al., 2004; McInnes et al., 2003; Renz et al., 2003; Zentall, 1988). These listening comprehension studies show that those with ADHD have difficulty in higher-order language processes, such as comprehending figurative language (Bignell & Cain, 2007) and answering inferential questions (McInnes et al., 2003). In addition, when comprehension is assessed by having individuals retell what they have heard, those with ADHD show deficits in organization and coherence (Purvis & Tannock, 1997; Tannock, Purvis, & Schachar, 1993), and sometimes recall less information (Lorch et al., 2004; Tannock et al., 1993; Zentall, 1988).

Given the comorbidity of word decoding problems and ADHD, one might expect that reading comprehension would be similarly, if not more, impaired than listening comprehension. However, the research on ADHD and reading comprehension presents a mixed picture: some studies indicate that individuals with ADHD do have reading comprehension difficulties (Brock & Knapp, 1996; Gregg et al., 2002; Samuelsson et al., 2004), while others present inconclusive findings (Ghelani, Sidhu, Jain, & Tannock, 2004). We can identify three methodological reasons for this mixed picture.

One reason is whether and how the studies controlled for word reading skill. Because word decoding is a basic component of reading comprehension, if word decoding is not controlled in studies of ADHD, then it is unclear whether difficulties in reading comprehension stem from the attention deficit or a decoding deficit. Even when studies recognize this confound and attempt to control for it, the stringency of the control varies.

A second, related issue is how the control group is defined. Determining whether individuals with ADHD display deficits is largely a product of who they are compared to. For example, some studies control for age (Brock & Knapp, 1996), while others do not (Samuelsson et al., 2004); some consider IQ (Ghelani et al., 2004), while others do not (Brock & Knapp, 1996); some match on decoding ability (Brock & Knapp, 1996), while others do not (Samuelsson et al., 2004).

The third reason for this mixed picture is that reading comprehension tests can differ in their attentional demands (Keenan & Meenan, in press). Test differences in length of texts (single sentences to long passages), in how meaningful and engaging texts are, and the method of assessment (Keenan, Betjemann, & Olson, 2008) can create differences in attentional load and thus influence the degree to which one might see the consequences of attention or executive function deficits (Cutting, Materek, Cole, Levine, & Mahone, 2009). Many studies examining reading comprehension in ADHD have used multiple-choice or cloze (i.e., fill in the blank) assessment formats (e.g., Ghelani et al., 2004; Gregg et al., 2002; Samuelsson et al., 2004). Such formats are easy to score, but they often are poor assessments of the reader's understanding because they contain a large number of passage-independent questions, as shown for the Nelson-Denny Reading Test by Coleman, Lindstrom, Nelson, Lindstrom, and Gregg (2010) and for the Gray Oral Reading Test (GORT) by Keenan and Betjemann (2006).

To illustrate how these methodological considerations complicate interpretation of findings, consider Gregg et al.'s (2002) study of the reading and comprehension skills of undergraduates. Participants in one group were clinically diagnosed with ADHD and were not diagnosed with a comorbid learning disability. Although less than 6% had previously been diagnosed as having decoding, reading rate, or spelling problems, Gregg et al. found that those with ADHD scored significantly lower than controls on several measures of decoding and spelling. Thus, when they report that individuals with ADHD display reading comprehension difficulties, it is unclear whether the comprehension differences between the two groups were related to their attention deficits or decoding deficits. Furthermore, they used the Nelson-Denny Reading Test, which because of the passage independence problem mentioned above, might mean that individuals with ADHD display knowledge differences rather than reading comprehension difficulties.

Brock and Knapp (1996) also assessed the reading comprehension skills of individuals with ADHD. They controlled for reading ability by first excluding all participants who were in a special education program due to reading disability and then matching the remaining children with ADHD to controls on reading ability, measured by Letter-Word Identification (Woodcock-Johnson III Tests of Achievement; Woodcock, MacGrew, & Mather, 2001). In addition, the two groups were matched on grade level, age, and parents' level of education. All participants (mean age = 10.6) were Inattentive type. Participants read passages, and their comprehension was assessed in three ways: (a) a cloze task, in which every tenth word of the original passage was deleted, (b) a title creation task, and (c) identifying the main ideas of the text. They found that compared to controls, children with ADHD showed deficits on all three measures, despite controlling for reading ability, and they concluded that children with ADHD have difficulties remembering words from the text (i.e., micro-comprehension) as well as pulling out the main ideas (i.e., macro-comprehension).

Contrary to these findings,Ghelani et al. (2004) suggested that 14–17 year olds with ADHD generally did not perform more poorly than controls on oral reading comprehension. They assessed oral reading comprehension with the GORT-4 and silent reading comprehension with the Gray Silent Reading Test (GSRT), which is similar to the GORT except for silent reading. As noted above, the GORT has been shown to be an insensitive measure of comprehension (Keenan & Betjemann, 2006) because its multiple-choice questions have significant problems with passage independence. Ghelani et al. did not find an ADHD reading comprehension deficit based on GORT comprehension performance, but did on the GSRT, although this effect went away when they controlled for IQ differences. Thus, the results are difficult to interpret both because of the inconsistency in findings between their tests and the limitations of the assessment instruments.

Methodological difficulties aside, another limitation of the literature is that although it suggests that individuals with ADHD likely have some type of reading comprehension difficulty, it does not tell us much about the nature of this difficulty. With the exception of Brock and Knapp's (1996) study in which participants were asked to identify the text's central ideas, previous work has relied on multiple-choice and cloze format items. If we are to generalize to classroom performance, we need to assess comprehension by examining the mental model that is constructed during comprehension and by measuring how well it is retained. Of particular interest is how ADHD impacts understanding and recalling a text's most central information.

Centrality Deficit

As individuals comprehend a passage, they attend to the text ideas and build a mental representation of the passage by forming connections among the passage's ideas that are related to one another. In the end, the ideas with the most connections (i.e., the ideas most closely related to the greatest number of other ideas in the passage) emerge as central, or important, to the passage's overall message, and those ideas with fewer connections are less important, or peripheral, to the passage. By forming the appropriate connections, the comprehender builds a coherent representation of the text (Graesser, Singer, & Trabasso, 1994; Keenan, Baillet, & Brown, 1984; Kintsch, 1974; van den Broek, 1988).

Miller & Keenan (2009, 2011) found that when word identification processes are not automatic, such as in the case of children with word decoding deficits or individuals reading in a foreign language, readers redirect cognitive resources away from forming connections among the text's ideas in order to cope with their word identification problems. As a result, their mental representation of the text is less coherent, and they show what Miller & Keenan labeled the *centrality deficit*. The centrality deficit is a deficit in retention of the central ideas of the text compared to control readers. Specifically, those for whom word identification is not automatic show a significantly greater deficit in the recall of central ideas compared to the controls than in their recall of peripheral ideas. Both groups retain central ideas better than peripheral ideas, what is called the *centrality effect*. However, the slope of the centrality effect is much flatter for the struggling readers than for controls.

If we think about how ADHD might impact comprehension processes, it seems that it may similarly strain the pool of cognitive resources available for forming connections among text ideas. Even when children with ADHD do not have comorbid word decoding problems, it could be that their reduced attentional resources may impair forming text connections so that central information may not emerge in their text representation to the same degree that it does for non-ADHD comprehenders, leading to a centrality deficit. In fact, a number of studies by Lorch and colleagues have provided data that support this idea. All of these data are from listening comprehension tasks. They had children either retell passages that they had listened to or tell about television shows that they had watched, and they found that compared to controls, children with ADHD showed a centrality deficit – a greater deficit relative to controls in the recall of central than peripheral information, even though they recalled more central than peripheral information (Flake et al., 2007; Lorch et al., 1999; Lorch et al., 2004).

Current Study

Children with ADHD may show a centrality deficit when listening because of the fleeting nature of the auditory information. A television show or an auditory story continues regardless of the listener's attention. Therefore, a child who has difficulties in sustaining attention might show particular problems in the auditory domain. Of interest is whether centrality deficits also obtain for reading comprehension. If one controls for word decoding difficulties, the centrality deficit may not manifest when reading, because the requirement of having to identify the words may make the task more attention focusing, or alternatively, deficits in attention can be compensated by going back and rereading.

The present study therefore assesses how ADHD impacts reading comprehension by examining whether a centrality deficit is evident in the retellings of a multi-sentence passage that children with ADHD have read. Because we know that word decoding problems can produce a centrality deficit (Miller & Keenan, 2009) and because word decoding problems are often comorbid with ADHD, we match controls and children with ADHD on word decoding skill so that we can examine whether ADHD leads to a centrality deficit beyond that associated with word decoding. We examine how well children with ADHD compare to controls of the same age who were matched on word-reading skill in forming a text representation that distinguishes central and peripheral information, allowing them to recall the text's most important ideas. Sustaining their attention on the words on the page might decrease distractibility and enable them to do as well as controls. Alternatively, their attention problems may be broader than just what has been observed with listening so that it also impacts their reading comprehension.

We will also examine how ADHD is related to a variety of cognitive skills and the degree to which these skills provide the cognitive underpinnings of understanding and remembering central information. The children in our study were assessed on measures of working memory, inhibition, processing speed, and IQ, and we relate their performance on these measures to their ability to process and retain the text's central information. Individuals with ADHD are known to show deficits in inhibition (Willcutt et al., 2001), working memory (Barkley, 1997; Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005), processing speed (Chhabildas, Pennington, & Willcutt, 2001; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005; Woods, Lovejoy, & Ball, 2002), and IQ (Ghelani et al., 2004). We attempt to bring new insights into the cognitive underpinnings of comprehension deficits in children with ADHD by exploring how each of these cognitive variables is related to comprehending and remembering central information.

Method

Participants

Twenty-seven children with ADHD (9.16–10.6 years) and 76 control children without ADHD (8.94–11.22 years) participated in the study. They were tested as part of a larger study of comprehension skills affiliated with our learning disabilities research center. To examine how ADHD impacts the centrality deficit unconfounded by word decoding difficulties, we matched the 27 children with ADHD to 27 of the non-ADHD controls on a word reading composite score (see Table 1 for descriptives). The word reading composite was created by combining the age-adjusted z-scores of two single-word reading measures: (1) Timed Oral Reading of Single Words (Olson, Forsberg, Wise, & Rack, 1994), which assesses word reading accuracy using a series of increasingly difficult words presented on a computer screen, and for which all correct responses must be initiated within 2 seconds of the word's presentation, and (2) Peabody Individual Achievement Test[1] (PIAT; Dunn & Markwardt, 1970) Word Recognition subtest, which is an untimed measure of reading increasingly difficult words until reaching an error criterion. The reading measures were standardized based on the larger study's sample, and the reading skills of the two groups spanned a broad range (ADHD: -2.43 – 1.33; Control: -2.41 – 1.31).

We administered the DSM–III–R (APA, 1987) parent-report version of the Diagnostic Interview for Children and Adolescents (DICA–P; Reich & Welner, 1988) to parents to assess symptoms of oppositional defiant disorder, conduct disorder, generalized anxiety disorder, and major depressive disorder (see Table 1).

ADHD Group Definitions—ADHD was defined by DSM-IV criteria (APA, 2000). Using the Disruptive Behavior Rating Scale (DBRS; Barkley and Murphy, 1998), parents and teachers rated the 18 DSM-IV ADHD symptoms. Parent and teacher ratings were combined by positively coding each symptom if it was endorsed by either the parent or the teacher (Lahey et al., 1994). Consistent with DSM-IV criteria, participants were categorized as ADHD only if symptoms were present before age seven and if these symptoms caused significant functional impairment across two or more settings. Participants with six or more Inattentive symptoms but less than six Hyperactive/Impulsive symptoms were categorized

[1]The individualized testing of our sample took place over many years. During that time, newer versions of some of our tests came on the market. However, to maintain continuity with earlier data collection on the project, we needed to continue to use the earlier versions. What typically varies across versions are only the norming data used to compute standard scores. Our analyses do not use standard scores, but rather are based on our standardizing the raw scores for each test.

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as Predominantly Inattentive type. Participants with fewer than six Inattentive symptoms but more than six symptoms on the Hyperactive/Impulsive dimension were categorized as Predominantly Hyperactive/Impulsive type. Participants with six or more symptoms on both dimensions were identified as Combined type. Participants included all types (14 Predominantly Inattentive; 4 Predominantly Hyperactive/Impulsive; 9 Combined). Controls did not meet DSM-IV criteria for any type of ADHD.

Materials

Reading passage—Participants read the *Amelia Earhart* passage from the Qualitative Reading Inventory – III (QRI; Leslie & Caldwell, 2001). The passage is 263 words long and 4th grade reading level.

Defining centrality—Centrality of the passage's idea units was defined using importance ratings obtained from undergraduates. The QRI provides an idea checklist for each passage. The *Amelia Earhart* passage checklist consists of 47 idea units. After reading the passage, 17 undergraduates rated the importance of each idea on the checklist to the overall meaning of the passage using a 0 – 7 Likert scale that ranged from the idea being "unimportant to the passage" to "very important to the passage". We calculated a mean rating for each idea unit; the ratings had high reliability estimates (ICC = .88, $p < .001$) and formed a normal distribution, which was divided into central and peripheral ideas using a median-split.

IQ—Verbal and Performance (i.e., Non-verbal) IQ was assessed by the Weschler Intelligence Scale for Children-Revised (WISC-R; Weschler, 1974).

Working memory—A working memory (WM) composite was formed from two measures: (1) *Sentence Span*: Sentences were aurally presented to participants with the final word missing. Participants had to supply the missing word and eventually repeat all the missing words from each set, which consisted of between two and five sentences (Siegel & Ryan, 1989). (2) *Counting Span*: Children counted aloud the number of yellow dots on a series of cards. At the end of each set, they stated in order the number of yellow dots that appeared on each card in the set (Case, Kurland, & Goldberg, 1982; Kuntsi, Stevenson, Oosterlaan, & Sonuga-Barke, 2001).

Processing speed—Two processing speed composites were formed: verbal and motor. The verbal processing speed (PS) composite included measures of *Rapid Automatized Naming,* which requires participants to name a set of stimuli – colors, letters, numbers, or pictures – as accurately and quickly as possible in 15 seconds (Compton, Olson, DeFries, & Pennington, 2002).

The motor PS composite included the following variables: (1). *WISC-R Coding*. Participants copy symbols associated with particular digits, based on a key at the top of the page. Participants fill in the appropriate symbol below each digit. The dependent measure is the total number correct after two minutes. (2). *WISC-R Symbol Search*. Children are given rows of symbols and asked to mark whether or not the target symbols appear in each row. (3). *Colorado Perceptual Speed Test.* Letter strings are organized into phonetically similar letters (e.g. bceg), phonetically dissimilar letters (e.g. bhsf), and pronounceable nonwords (e.g. pelb). The task requires fast and accurate recognition of a target stimulus from an array of stimuli. (4). *ETS Identical Pictures Test* (French, Ekstrom, & Price, 1963) is similar to the Colorado Perceptual Speed Test, but uses pictures rather than letters. (5). The *Trailmaking test* (Reitan & Wolfson, 1985) asks children to draw a path to connect a series of numbered or lettered circles as quickly as possible.

Inhibition—The inhibition composite was based on combined performance on *Gordon Vigilance* (Gordon, 1983), *Gordon Distractibility* (Gordon), and the *Stop Signal Task* (Logan, Schachar, & Tannock, 1997; Schachar, Mota, Logan, Tannock, & Klim, 2000). For Gordon Vigilance, participants press a specified button in response to a correct two-digit series (*1* followed by *9*) and inhibit their response to all other sequences. Gordon Distractibility is similar, but numbers flash in three columns instead of only one, and the participant is told to attend only to the center column. Errors of commission are the dependent measure for the inhibition domain. The *Stop Signal task* is a computerized measure of inhibitory control. On primary task trials, the letters X or O are presented in the center of the screen, and the participant responds by pressing the corresponding key on the keyboard. On stop-signal trials, the same visual stimulus appears, but an auditory tone is also presented shortly after the X or O appears on the screen. The participant is instructed to press the X or O key as rapidly as possible for each trial, but to inhibit the key press on each of the trials on which the tone is presented. The task yields a Stop Signal Reaction Time, which is an estimate of inhibition speed.

Procedure

Prior to the study, parents and teachers of the participants completed the DSM-IV Checklist to assess ADHD symptoms, and telephone interviews screened for known environmental brain insults or other rare etiologies of ADHD symptoms; such participants were excluded from the study. Stimulant medication was discontinued 24 hours prior to testing. Participants took part in two full days of cognitive testing. The WISC-R, RAN, Colorado Perceptual Speed, Identical Pictures tasks and the decoding measures were administered in an initial testing session. The Sentence Span Task, Trailmaking Test, Gordon Diagnostic System, and Stop Task were completed during a second session scheduled approximately one month later.

Reading comprehension tests were also administered on the second day of testing. As part of this battery, participants completed the QRI, which required them to read grade-appropriate passages aloud and immediately recall them. The child's retelling was audio-recorded, transcribed, and later scored using the QRI idea unit checklist (described in the Defining Centrality section). Participants were credited for recalling a given idea unit if they stated the idea verbatim or represented the gist of the idea using synonymous language. The recalls were scored by research assistants who were blind to both the centrality of the idea units and the participants' ADHD status. Thirty-one recalls were scored by multiple raters, and inter-rater reliability of this subset was very high (ICC = .90, $p < .001$). Immediately following the free recall, participants answered six open-ended questions about the story.

Results

Retellings

We used a 2 × 2 mixed design ANCOVA with group (ADHD, Reading-matched Controls) as a between-subjects factor and centrality of recalled information (Central, Peripheral) as a repeated-measures factor to assess the effect of these variables on the amount recalled. Gender was entered as the covariate because the gender distribution was significantly different across the two groups (see Table 1). There was a significant interaction between group and the centrality of the information recalled ($F(1, 51) = 6.01$, $p = .02$, partial $\eta^2 = .11$). As shown in Figure 1, this significant interaction indicates that children with ADHD showed a centrality deficit – a greater difficulty recalling central than peripheral information compared to controls.

The main effect of group was marginally significant ($F(1, 51) = 3.52$, $p = .07$; partial $\eta^2 = .07$), with children with ADHD recalling fewer ideas than controls (ADHD adjusted mean = .34, SE = .03; Control adjusted mean = .42, SE = .03). The main effect of centrality was significant ($F(1, 51) = 29.23$, $p < .001$; partial $\eta^2 = .36$), indicating that participants recalled a greater proportion of central than peripheral ideas (Central: adjusted mean = .44, SE = .02; Peripheral: adjusted mean = .33, SE = .02).

Comprehension Questions

We used a one-way ANCOVA, controlling gender, to compare the performance of children with ADHD and their word reading-matched controls on the open-ended comprehension questions that followed the recall. We found no significant difference between the two groups (ADHD: adjusted mean = 3.77, SE = .27; Controls: adjusted mean = 3.94, SE = .27; $F(1, 51) = .17$, $p = .68$, partial $\eta^2 = .003$.). The lack of difference between the children with ADHD and controls on the comprehension questions suggests that children with ADHD were as engaged in the tasks as the controls and thus that their centrality deficit is not because they failed to put forth a conscientious performance.

Cognitive Underpinnings of the Centrality Deficit

We assessed correlations among the number of ADHD symptoms (divided into Hyperactive/ Impulsive and Inattention symptoms), the amount of central ideas recalled, word reading ability, and cognitive variables (WM, inhibition, verbal processing speed, motor processing speed, verbal IQ, and performance IQ; see Table 2). We included the full sample ($n = 103$) in order to examine how the number of inattention and hyperactive/impulsive symptoms measured continuously, rather than dichotomized into groups, relate to central recall and the cognitive variables. Predictably, the proportion of central ideas recalled was negatively correlated with the number of hyperactive/impulsive symptoms and the number of inattention symptoms, indicating that the more ADHD symptoms a child displayed, the fewer central ideas he recalled. Central recall was positively correlated with all the cognitive variables.

We used a series of hierarchical linear regressions to model the influence of cognitive skills on recalling central ideas and to test whether any of these cognitive skills mediate or moderate the relationship between ADHD symptoms and the ability to recall central ideas. In each regression, the dependent variable was the proportion of central ideas recalled, and word reading ability and gender were controlled in the first step. Each regression included three predictors in the second step: (a) ADHD Symptoms (total number of symptoms, mean centered), (b) standardized cognitive variables (we ran separate regressions for inhibition, WM, verbal PS, motor PS, verbal IQ, and performance IQ), and (c) the interaction of ADHD Symptoms×Cognitive Variables. The interactions tested whether any of the cognitive variables moderated the relationship between ADHD symptoms and recall of central ideas.

Results of the six regression models are presented in Table 3. After controlling for word reading ability and gender, higher working memory scores significantly predicted recall of central ideas. The other cognitive measures (inhibition, verbal processing speed, motor processing speed, verbal IQ, performance IQ) were not significantly associated with the ability to recall central ideas. Given that WM was predictive of the ability to recall central ideas, we further probed whether WM mediated the relationship between ADHD symptoms and central recall, when controlling for word reading ability and gender.

We examined mediation according to the methods outlined in Baron & Kenny (1986): (1) After controlling for word reading ability and gender, the independent variable (ADHD symptoms) significantly affected the mediator (WM; see Figure 2), (2) the independent variable (ADHD symptoms) significantly affected the dependent variable (proportion of central ideas recalled) in the absence of the mediator (WM), and (3) the mediator (WM) had a significant unique effect on the dependent variable (proportion of central ideas recalled). Mediation occurs if the effect of the independent variable on the dependent variable shrinks upon the addition of the mediator to the model. If the effect of the independent variable on the dependent variable is no longer significant upon the addition of the mediator to the model, the mediator is then considered to completely mediate the relation between the independent and dependent variables. According to these criteria, WM completely mediated the relationship between ADHD symptoms and the proportion of central ideas recalled.

Discussion

Although some studies show that ADHD is associated with reading comprehension difficulties (Brock & Knapp, 1996; Gregg et al., 2002; Samuelsson, et al., 2004), the findings are inconsistent (Ghelani et al., 2004). One major reason for inconsistent findings is that studies often confound ADHD with comorbid word decoding deficits, thus blurring whether difficulties stem from decoding or comprehension. In addition, studies that do show difficulties have not provided insight into the mechanisms associated with comprehension difficulties, partly owing to their use of multiple-choice or cloze tests. In this study, we carefully matched children with ADHD and non-ADHD controls on word reading ability in order to assess the impact of ADHD on reading comprehension, unconfounded by word reading differences. We examined not only how well children could retell a passage and answer questions about it, but also how well they retained the central information versus more peripheral information. By comparing the proportion of central and peripheral ideas recalled by children with ADHD to that of controls, we were able to gain insights into the nature of comprehension difficulties associated with ADHD in building a text representation.

We found that children with ADHD and controls both recalled more central than peripheral ideas; however, directly comparing the two groups' recalls revealed that the children with ADHD showed difficulty compared to controls in the recall of central ideas. This study is the first to find this reading comprehension difficulty among children with ADHD, although a similar pattern has been reported in younger children with ADHD as they listened to stories or watched cartoons (Flake et al., 2007; Lorch et al., 1999; Lorch et al., 2004). Because recalling a passage's most central information is the goal of reading, this centrality deficit is an important indicator that the reading comprehension skills of children with ADHD warrant attention.

We suggest that the centrality deficit occurs because children with ADHD do not form all the appropriate connections among the text's related ideas. Typically, central ideas emerge as central because they are the most interconnected ideas in the text representation. One explanation for what might hinder children with ADHD from forming these connections is that their deficit requires them to devote more cognitive resources than typical readers to sustaining attention, and consequently they are left with fewer cognitive resources to devote to higher level comprehension, including connecting related ideas to form a coherent mental representation.

Support for this theoretical explanation of the centrality deficit comes from the recall patterns of two other groups: children with reading disability (RD) (Miller & Keenan, 2009) and adult foreign language learners (Miller & Keenan, 2011). Like children with ADHD, these groups have limited cognitive resources for comprehension, and show a centrality deficit because their resources are being allocated to other processes. The present research extends these findings on tradeoffs of cognitive resources due to word identification problems and shows that trading off cognitive resources to sustaining attention results in the same centrality deficit.

Another major contribution of this study is that we explored how cognitive variables are related to ADHD symptoms and the extent to which they might explain the cognitive underpinnings of the centrality deficit. We assessed the contribution of six cognitive variables: inhibition, working memory, verbal processing speed, motor processing speed, verbal IQ, and performance IQ. After controlling for word reading ability and gender, only one cognitive measure contributed unique variance to the ability to recall central ideas: WM. A follow-up test of mediation indicated that WM completely mediated the relationship between ADHD symptoms and the ability to recall central ideas. This is consistent with our theoretical explanation of the centrality deficit: comprehension is an ongoing process that requires readers to continuously update their mental representation by forming new connections as they proceed through the text. It is WM that enables readers to hold previously presented ideas online and simultaneously integrate new ideas into their mental representation. Previous studies have shown WM to be related to other measures of reading comprehension as well (Borella, Carretti, & Pelegrina, 2010; Christopher et al., 2012; Keenan & Meenan, in press; Locascio, Mahone, Eason, & Cutting, 2010; Swanson, Howard, & Sáez, 2007).

We could not examine the Inattentive, Hyperactive/Impulsive, and Combined subtypes in this study because we had only four children representing the Hyperactive/Impulsive subtype. Now that we have established that ADHD impacts the ability to represent and recall central information, future work should address whether the centrality deficit is equally likely to be displayed by all three subtypes. Future work should also examine the extent to which our findings generalize to other passage topics, as well as other genres of discourse.

The present study illustrates the value of examining the quality of readers' memory for text. Here children with ADHD did not have difficulty answering open-ended comprehension questions. Only by examining the proportion of central and peripheral ideas recalled by the two groups did we discover that children with ADHD did indeed show a noteworthy difficulty in reading comprehension, and it was in the most central ideas. The comprehension questions in this study apparently were not sensitive enough to reveal this difficulty, perhaps because half of them targeted ideas that were explicitly stated in the text. It is possible that answering such questions does not require the reader to build a coherent representation of the text, but rather can be answered by rote memorization. This reading comprehension difficulty would likely have been overlooked if, like the majority of previous studies in this area (e.g., Ghelani et al., 2004; Gregg et al., 2002; Samuelsson et al., 2004), we had used a multiple-choice or cloze format. We hope that our findings encourage investigators and clinicians to move beyond test formats that expedite administration and scoring so as to achieve greater insights into how developmental disorders, such as ADHD, impact comprehension processes.

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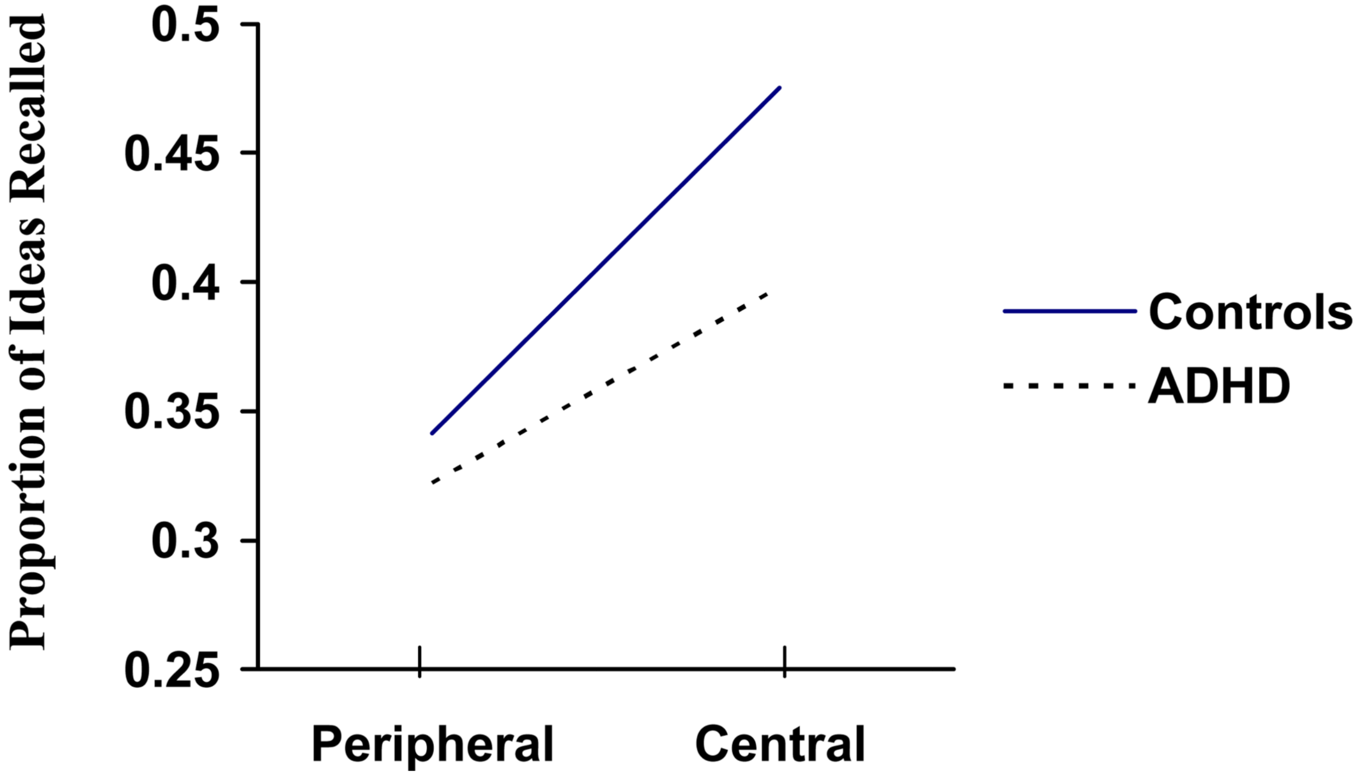

Figure 1.
Proportion of central and peripheral ideas recalled by children with ADHD and word reading-matched controls. The unadjusted means are displayed.

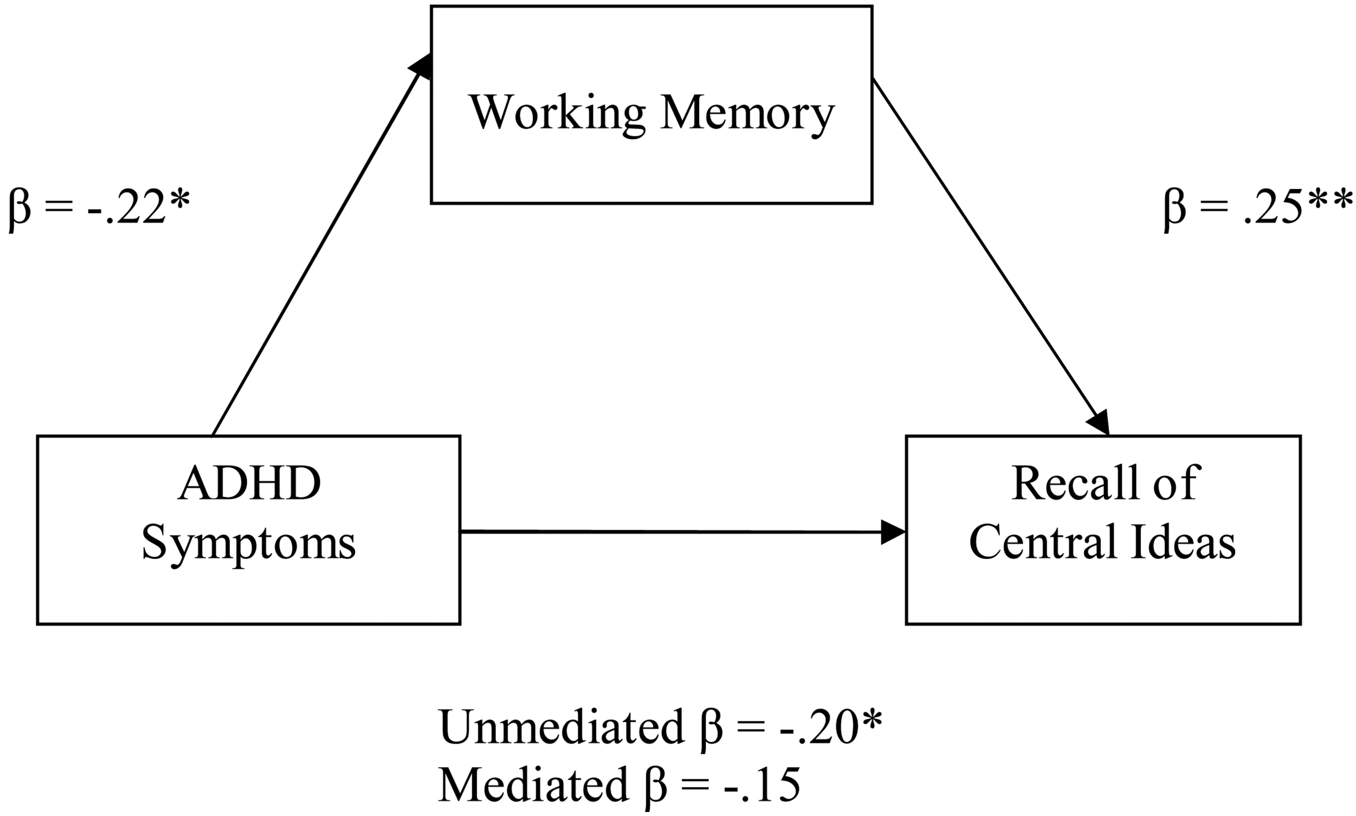

Figure 2.
Working memory completely mediates the relationship between ADHD symptoms and the ability to recall central ideas. Word reading ability and gender were controlled in this test of mediation. * $p < .05$, ** $p < .01$.

Table 1

Descriptive Statistics

	ADHD (*n* = 27)	**Word Reading-matched Controls (n= 27)**
Group Defining Variables		
ADHD Symptoms	11.89 (3.53)	1.26*** (1.79)
Inattention	7.41 (1.60)	.89*** (1.31)
Hyp/Imp	4.48 (3.23)	.37*** (.97)
Word Reading *z*-score	−.64 (.91)	-.68 (.93)
Demographics		
Age	9.78 (.35)	9.89 (.55)
Gender (% female)	33.3	81.5***
Father's education (years)	14.69 (2.45)	15.67 (2.43)
Mother's education (years)	14.78 (2.49)	15.04 (2.41)
Ethnicity (% Caucasian)	90.0	96.3
Comorbid Diagnosis (% diagnosed)		
Oppositional Defiant Disorder	48.1	3.7***
Conduct Disorder	28.0	3.7*
Generalized Anxiety Disorder	15.4	7.7
Major Depression	18.5	7.4
Cognitive Variables		
Inhibition	−.39 (1.10)	.26* (.91)
Verbal Processing Speed	−.35 (.61)	.00 (.77)
Motor Processing Speed	−.29 (.55)	.08 (.67)
Working Memory	−.31 (.59)	.00 (.78)
Full Scale IQ	105.78(8.79)	106.96 (11.36)
Verbal IQ	108.96 (11.45)	110.00 (13.83)
Performance IQ	101.22 (10.14)	102.56 (9.69)

Note. Asterisks indicate the statistical significance of group differences:

* $p < .05$,

** $p < .01$,

*** $p < .001$. Except where noted, means (with standard deviations) are presented.

Table 2

Correlations Among Recall Variables, ADHD Symptoms, and Cognitive Variables Across Total Sample

	1	2	3	4	5	6	7	8	9
1. Central Recall	1								
2. Word Reading	.37	1							
3. Hyp/Imp Symptoms	−.23	−.10	1						
4. Inattention Symptoms	−.22	−.21	.64	1					
5. WM	.33	.27	−.17	−.24	1				
6. Inhibition	.25	.12	−.45	−.37	.34	1			
7. Verbal PS	.29	.36	−.25	−.37	.31	.27	1		
8. Motor PS	.23	.43	−.31	−.42	.39	.38	.62	1	
9. Verbal IQ	.36	.67	−.11	−.15	.28	.24	.31	.43	1
10. Perf IQ	.20	.33	−.09	−.25	.26	.24	.39	.69	.44

Note. Central Recall = proportion of central items recalled; Word reading = word reading composite score; Hyp/Imp symptoms = number of DSM-IV hyperactive/impulsive symptoms; Inattention symptoms = number of DSM-IV inattention symptoms; WM = working memory composite score; Inhibition = inhibition composite score; Verbal PS = verbal processing speed composite score; Motor PS = motor processing speed composite score; Verbal IQ = WISC-R Verbal IQ; Perf IQ = WISC-R Performance IQ

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Table 3

Results of Hierarchical Regressions That Examine Executive Function Predictors of the Proportion of Central Ideas Recalled, Controlling for Word Reading Ability and Gender

	B	**SE(B)**	**β**	***t***	***p***
Model 1					
ADHD sx	.00	.00	−.11	−1.00	.34
Inhibition	.02	.02	.16	1.44	.15
Inhibition×ADHD sx	.00	.00	.01	.12	.90
Model 2					
ADHD sx	.00	.00	−.16	−1.59	.12
WM	.03	.02	.21	2.16	.03
WM×ADHD sx	.00	.00	−.05	−.54	.59
Model 3					
ADHD sx	.00	.00	−.13	−1.27	.21
Verbal PS	.02	.02	.13	1.28	.20
Verbal PS×ADHD sx	.00	.00	.06	.61	.55
Model 4					
ADHD sx	−.01	.00	−.23	−1.99	.05
Motor PS	.00	.02	−.01	−.04	.97
Motor PS×ADHD sx	.00	.00	−.08	−.81	.42
Model 5					
ADHD sx	−.01	.00	−.23	−2.30	.02
Verbal IQ	.02	.02	.14	1.13	.26
Verbal IQ×ADHD sx	−.01	.00	−.18	−1.81	.07
Model 6					
ADHD sx	−.01	.00	−.20	−2.04	.04
Performance IQ	.01	.02	.06	.59	.56
Performance IQ×ADHD sx	.00	.00	−.11	−1.16	.25

Note. WM = Working Memory, PS = Processing Speed