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The origin of the centrality deficit in individuals with attention-deficit/hyperactivity disorder

Menahem Yeari[a], Eli Vakil[b], Lee Schifer[a] and Rachel Schiff[a]

[a]School of Education, Bar Ilan University, Ramat-Gan, Israel; [b]Department of Psychology and Leslie and Susan Gonda (Goldschmied) Multidisciplinary Brain Research Center, Bar-Ilan University, Ramat-Gan, Israel

ABSTRACT

Introduction: Studies have shown that skilled and disabled readers recall central ideas, which are important to the overall comprehension of the text, to a greater extent than peripheral, less important ideas after reading. However, readers with attention-deficit/hyperactivity disorder (ADHD) recall significantly fewer central ideas than skilled readers. The present study was designed to examine whether difficulties in identifying, attending, and/or retrieving central ideas underlie their *centrality deficit*.

Method: 28 adult university students with ADHD and 27 control students read three expository texts (successively) to summarize their central ideas, while their eye-movements were recorded. After reading, the participants recalled, recognized, and estimated the centrality level of *all* text ideas, which were divided into *central* and *peripheral* based on pretest ratings.

Results: The participants with ADHD recalled fewer central ideas than controls, although they recognized and estimated their centrality to the same extent as controls. Moreover, the participants with ADHD invested more time in rereading central ideas than peripheral ones, to a greater extent than controls.

Conclusions: The eye-movement data suggest that our university students with ADHD were aware of the reading task requirements, their difficulties, and the appropriate strategies for coping with them (i.e., rereading central ideas). More importantly, the present findings suggest that readers with ADHD have specific difficulty in retrieving central ideas that are available in their long-term memory. It supports the hypothesis that readers with ADHD establish fewer connections between text ideas during reading, and consequently benefit from a reduced number of retrieval cues after reading.

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Attention-deficit/hyperactivity disorder; centrality deficit; eye movements; reading comprehension; text recognition; text recall

Attention-deficit/hyperactivity disorder (ADHD) is a neurodevelopmental disorder characterized by elevated levels of inattention, impulsivity, and hyperactivity (Barkley, Murphy, & Fisher, 2008; *Diagnostic and Statistical Manual of Mental Disorders–Fifth Edition, DSM–5*, American Psychiatric Association, APA, 2013). It is a chronic condition that affects 5–10% of children before the age of seven, and persists into adolescence and adulthood in about 50% of the cases (Barkley et al., 2008; Lorch, Berthiaume, Milich, & van den Broek, 2007; Stern & Shalev, 2013). One prominent feature associated with ADHD is poor academic achievement in general (DuPaul et al., 2001; Frazier, Youngstrom, Glutting, & Watkins, 2007; Marshall, Evans, Eiraldi, Becker, & Power, 2014) and poor text comprehension in particular (Berthiaume, Lorch, & Milich, 2010; Cherkes-Julkowski, Stolzenberg, Hatzes, & Madaus, 1995; Ghelani, Sidhu, Jain, & Tannock, 2004; Martinussen & Mackenzie, 2015; McInnes, Humphries, Hogg-Johnson, & Tannock, 2003; Miranda, Mercader, Fernández, & Colomer, 2017; Stern & Shalev, 2013). In exploring the causes underlying this comprehension deficiency, researchers have found that adults and children with ADHD have more difficulties than their peers in remembering central (main) ideas, which are important to the overall comprehension of the text, after listening (Lorch et al., 1999, 2004), watching (Flake, Lorch, & Milich, 2007; Lorch et al., 2000), and, recently, reading narratives (Miller et al., 2013). Several hypotheses have been suggested to explain these difficulties (Lorch et al., 2007; Miller et al., 2013). However, more research was required to test these hypotheses empirically. The present study was designed to examine these hypotheses and explore the origin of the difficulties experienced by adults with ADHD in remembering central ideas after reading.

Centrality deficit in individuals with ADHD

Identifying central ideas during text processing and allocating sufficient cognitive resources to process and encode these ideas in long-term memory is a crucial

CONTACT Menahem Yeari Menahem.Yeari@biu.ac.il School of Education, Bar Ilan University, Ramat-Gan 52900, Israel

skill for successful comprehension and learning of texts (Gersten, Fuchs, Williams, & Baker, 2001; Jitendra, Kay Hoppes, & Xin, 2000; Meyer, Brandt, & Bluth, 1980; Stevens, Slavin, & Farnish, 1991). Limitations on attentional and working memory resources require comprehenders to regulate their text processing wisely and efficiently, while information is gradually accumulated during text comprehension (Britton, Muth, & Glynn, 1986; Cirilo & Foss, 1980; Hyönä & Niemi, 1990; Yeari, Oudega, & Broek, 2017; Yeari, van den Broek, & Oudega, 2015). Consistent with this notion, numerous studies have shown that skilled readers comprehend and remember central ideas to a greater extent than peripheral, less important ones (Britton, Meyer, Hodge, & Glynn, 1980; Britton et al., 1986; A. L. Brown & Smiley, 1977; Cirilo & Foss, 1980; Hyönä & Niemi, 1990; Keenan & Brown, 1984; Kintsch, Kozminsky, Streby, McKoon, & Keenan, 1975; Meyer, 1975; Thorndyke, 1977; Yeari, 2017; Yeari et al., 2015). Interestingly, superior recall of central ideas after reading a text, termed as *centrality effect*, has been observed in individuals with learning disabilities as well, albeit in a weaker manner than in skilled readers (Curran, Kintsch, & Hedberg, 1996; Hansen, 1978; Miller & Keenan, 2009; Smiley, Oakley, Worthen, Campione, & Brown, 1977). Specifically, disabled readers recalled more central ideas than peripheral ones (i.e., a centrality effect). However, they recalled significantly fewer central ideas than their skilled peers, whereas no difference was found in the recall of peripheral ideas by both groups. This inferior recall of central ideas by readers with learning disabilities has been labeled as *centrality deficit* (Miller & Keenan, 2009).

Recently, Miller et al. (2013) demonstrated this centrality deficit in readers with ADHD. In their study, children with and without ADHD read aloud and immediately recalled a grade-appropriate narrative. Forty-seven information units, identified in the text, were rated for centrality by undergraduates and were then divided into central and peripheral unit groups using a median-split. Miller et al. found that children with ADHD recalled more central ideas than peripheral ones (i.e., centrality effect), albeit fewer than controls (i.e., centrality deficit). This centrality deficit was attributed to attention deficiencies, because the two groups were matched on word reading accuracy and recognition. In addition, Miller et al. examined the relationship between the centrality deficit and a variety of cognitive–verbal competencies, such as working memory, verbal and motor processing speed, response inhibition, and verbal and performance IQ. Using regression analyses, they found that only working memory capacity was significantly associated with the size of centrality deficit over and above the associations obtained with the other constructs. Based on these results, Miller et al. suggested that children with ADHD possess fewer working memory resources to establish conceptual connections between text ideas during reading and, consequently, benefit from fewer cues to retrieve text ideas from long-term memory after reading. They added that the retrieval of central ideas is impaired to a greater extent than that of peripheral ideas, because central ideas constitute more connections with other ideas in the text than peripheral ones (Trabasso & Sperry, 1985; van den Broek, 1988). The present study examined this and alternative hypotheses, described in the next section.

Possible origins of the centrality deficit in individuals with ADHD

Deficient attention regulation

Several hypotheses can explain the origin of the centrality deficit found in individuals with ADHD. One hypothesis naturally concerns the control of attention allocated to process central and peripheral ideas. According to the selective attention hypothesis (Britton, Meyer, Simpson, Holdredge, & Curry, 1979; Goetz, Schallert, Reynolds, & Radin, 1983; Gomulicki, 1956; Meyer, 1975), central ideas are better remembered than peripheral ideas after reading, because readers allocate more attention during reading to processing ideas that are perceived as highly important to the overall comprehension of the text. This hypothesis was supported by studies with skilled readers that have shown slower reading of central than peripheral ideas, in both a sentence-by-sentence reading setting (Britton et al., 1986; Cirilo & Foss, 1980) and a free-viewing reading setting, using eye-tracking methodology (Hyönä & Niemi, 1990; Yeari, 2017; Yeari et al., 2015). Note that in the latter setting, longer initial reading (i.e., first-pass) and more occurrences of rereading (i.e., regressions) were found for central than for peripheral ideas.

Consistent with the selective attention hypothesis, individuals with ADHD exhibit a centrality deficit because they have difficulties in *sustaining* sufficient attention in the processing of central ideas (e.g., O'Connell, Bellgrove, Dockree, & Robertson, 2004; Seidman, Biederman, Weber, Hatch, & Faraone, 1998; Stern & Shalev, 2013) and/or difficulties in *reducing* attention directed to the processing of peripheral ideas (e.g., Barkley, 1997; Fischer, Barkley, Smallish, & Fletcher, 2005; Quay, 1997). Practically, this hypothesis suggests that individuals with ADHD invest *less* time in (re)reading central ideas and/or *more* time in (re) reading peripheral ideas than individuals who do not exhibit a centrality deficit.

This possibility has never been examined before. However, it receives some support from a series of studies conducted by Lorch and her colleagues (Bailey, Lorch, Milich, & Charnigo, 2009; Landau, Lorch, & Milich, 1992; Lorch et al., 2000, 2004; Sanchez, Pugzles Lorch, Milich, & Welsh, 1999). In these studies, children with and without ADHD watched televised stories in the presence or absence of irrelevant toys placed near the television, while their eye gaze was monitored throughout the viewing session. They found that children with ADHD had more difficulties in answering comprehension questions than their comparison peers, only when the toys were present. Analyzing the eye gaze patterns indicated that the children with ADHD engaged in shorter glances at the television than controls when toys were present. These findings, although not analyzed separately for central and peripheral narrated events, support the notion that poor attention regulation may underlie the inadequate text processing exhibited by individuals with ADHD.

Retrieval cues shortage

An alternative hypothesis suggested to explain the centrality deficit in individuals with ADHD concerns their ability to establish conceptual connections between text ideas during reading, and, consequently, to produce retrieval cues in support of text recall after reading (Lorch et al., 2007; Miller et al., 2013). Retrieval cues, in this sense, refer to any information stored in long-term memory, whose retrieval during a recall task facilitates retrieval of text information due to its connection within the mental (network) representation of the text (Kintsch, 1998; Myers & O'Brien, 1998; Singer & Kintsch, 2001).

According to the causal network model (Trabasso & Sperry, 1985; van den Broek, 1988), central ideas are better remembered because they are conceptually connected with more ideas in the text than peripheral ideas, and consequently benefit from more retrieval cues during text recall. This model was supported by studies that have shown that recall proportions of text ideas were a positive function of the number of interconnections, especially causal, identified between text ideas and the centrality scores of text ideas received by human raters (Trabasso & van den Broek, 1985; Trabasso, van den Broek, & Suh, 1989; van den Broek & Trabasso, 1986). That is, text ideas that constituted more connections with other ideas received higher centrality scores and were recalled to a greater extent than text ideas that constituted fewer connections with other ideas.

Consistent with this model, scholars have suggested that individuals with ADHD exhibit centrality deficit because they establish fewer connections between text ideas, and therefore construct fewer retrieval cues to recall text ideas, especially central ones (Lorch et al., 2007; Miller et al., 2013). Miller et al. (2013), who found a unique association between working memory capacity and centrality deficit extent, suggested that children with ADHD do not have sufficient resources to retain multiple text ideas in working memory for identifying and constructing conceptual connections between them. Lorch et al. (2007) offered a similar hypothesis to explain the centrality deficit in children with ADHD, but on different grounds. In the televised stories studies, Landau et al. (1992) and Lorch et al. (2000) found that children with ADHD had more difficulties in answering integrative questions on implicit information ("why" questions) than literal questions on specific explicit details ("what" questions), particularly when they were distracted by the irrelevant toys. They therefore concluded that children with ADHD, who are more easily distracted by irrelevant information, have fewer resources available to establish connections between text ideas required for answering integrative questions.

Considering that this type of evidence (i.e., association with working memory capacity and difficulties in answering integrative questions) only indirectly supports the retrieval-cues-shortage hypothesis, further tests are required to reinforce this hypothesis. One way to examine the quality and availability of retrieval cues is by comparing performance on a text recall task, that requires readers to retrieve text ideas independently, with performance on a text recognition task, that requires readers to decide whether target ideas appeared in the text. According to memory theories (Gillund & Shiffrin, 1984; Hintzman & Curran, 1994; Jacoby, 1991; Koriat, 1993; Murdock, 1982; see Yonelinas, 2002; for a review), recall performance depends on effortful, deliberate search in long-term memory network (referred to as recollection processes), initiated and advanced by associated information retrieved by the reader (i.e., retrieval cues). Recognition performance, on the other hand, can rely on an effortless, automatic sense of familiarity (in addition to recollection processes), based on signal-detection-like processes and/or heuristic cues available during processing of the to-be-recognized information (e.g., the ease of processing). Therefore, the difference between recall and recognition performances is often attributed to the number and quality of retrieval cues available to the reader (e.g., Flexser & Tulving, 1978; Gillund & Shiffrin, 1984; Vakil, Greenstein, & Blachstein, 2010). The greater the difference is, the fewer and poorer the cues. In the present study, we adopted this method to examine the availability of retrieval cues in the recall of central and peripheral text ideas by individuals with ADHD.

Poor centrality estimation

Finally, a third hypothesis that may explain the centrality deficit in individuals with ADHD concerns their ability to distinguish between central and peripheral information. According to this hypothesis, individuals with ADHD do not prefer the processing and encoding of central ideas over peripheral ones during reading, and consequently their recall after reading, because they have difficulties in estimating centrality and identifying central ideas in texts. This kind of deficiency can originate in poor knowledge of text structures (e.g., protagonist's goals play a central role in narratives; Lynch & van den Broek, 2007; Stein & Glenn, 1979), which characterizes students with poor academic skills, such as students with ADHD. One finding that supports this hypothesis indicated that children with ADHD performed worse than their peers in a sorting task that required an explicit evaluation of the importance of televised story events they had watched earlier (Lorch, Milich, Astrin, & Berthiaume, 2006). Note, however, that the viewing setting in this study was accompanied with distracting sound probes (as a secondary task), to assess levels of engagement while watching central and peripheral events. Thus, further examination of centrality estimation is required under more natural conditions.

The present study

The present study was designed to explore the origin of the centrality deficit found in individuals with ADHD. Specifically, we examined the three potential impairments suggested by the hypotheses described above: (a) deficient attention regulation, (b) retrieval cues shortage, and (c) poor centrality estimation. To address these goals, adult students with and without ADHD underwent a series of tests during and after the reading of expository texts, whose ideas' centrality level was estimated in advance. Attention regulation was assessed by monitoring of eye-movements during reading, to measure the time and likelihood that central and peripheral ideas are (re)read (Hyönä & Niemi, 1990; Yeari, 2017; Yeari et al., 2015). Availability of retrieval cues was examined by comparing recall and recognition of text ideas (Vakil et al., 2010; Yonelinas, 2002). Centrality estimation was assessed by collecting centrality scores of text ideas after reading (Lorch et al., 2006). The purpose of reading was to summarize the main ideas of the texts. In contrast to previous studies, which instructed participants to read or listen to a text for overall comprehension and/or recall, we explicitly encouraged readers to identify and attend central information during reading. We thus ensured that a potential centrality deficit would not be an artifact of poor understanding or implementation of the strategies required to accomplish the reading task (e.g., readers with ADHD may memorize all text ideas to the same extent when asked to recall the whole text; see Yeari et al., 2015). Following the reading of the texts, the participants were asked to recall both central and peripheral information (in contrast to their primary summarizing goal) in order to examine centrality effect and deficit.

The presence of deficiency (i.e., a centrality deficit[1]) in each of the different target skills was examined by comparing the extent to which the processing of central ideas was superior to that of peripheral ideas (i.e., centrality effect size) in the ADHD and control groups.[2] Specifically, in case individuals with ADHD suffer from deficient *attention regulation* during reading, we expected to observe a smaller difference in the (re)reading of central and peripheral ideas in the ADHD than in the control group. The possible difficulty of individuals with ADHD in sustaining attention to central ideas and/or reducing attention to peripheral ideas should be expressed in the time they devote to process these ideas (Hyönä & Niemi, 1990; Yeari, 2017; Yeari et al., 2015). In case individuals with ADHD construct fewer *retrieval cues*, we expected to observe a smaller difference in recall, but not in recognition (or at least to a lesser extent), of central and peripheral ideas in the ADHD than in the control group. A shortage in retrieval cues due to poor representation of intertext connections (Lorch et al., 2007; Miller et al., 2013) ought to impair the recall of text ideas to a greater extent than the recognition of text ideas (Yonelinas, 2002). Finally, in case individuals with ADHD have difficulties in *estimating centrality*, we expected to observe a smaller difference in the centrality scores assigned to central and peripheral ideas in the ADHD than in the control group. Note that in this case, individuals with ADHD may also exhibit poor regulation of the time they devote to process central and peripheral ideas during reading. Nevertheless, this pattern of results would indicate poor centrality estimation, rather than deficient attention regulation. The presence of the latter deficiency is implied only if centrality estimation ability is preserved.

Method

Participants

28 students with attention disorder (8 males, M_{age} = 24.7 years, *SD* = 3.2) and 27 control students without attention disorder (11 males, M_{age} = 25.3 years, *SD* = 6.2) from Bar-Ilan University, Israel, participated in this study. The participants with attention disorder had a well-documented history of ADHD or attention-deficit disorder (ADD) based on earlier assessments by a professional diagnostician. Participants taking stimulant medication did not receive it for 18 hours prior to participation in the study. Individuals who were diagnosed as suffering from a neurological disorder (other than ADHD) and/or a specific reading or language disability did not participate in this study. All participants were native Hebrew speakers (the texts' language). They signed an informed consent form before beginning the study and received a payment of 80 NIS (worth about ~$22) for their participation at the end of the study. Ethical aspects of the research were reviewed and approved by the institutional review board (IRB) of Bar-Ilan University.

Apparatus

Eye movements were recorded using an SMI250 desktop-mounted eye-tracker of the SMI Company. Sampling frequency was 250 Hz, and spatial accuracy was approximately 0.4°. The texts and computerized tasks were presented on a 47 × 29-cm screen at a resolution of 1,680 × 1,050 pixels, at a distance of approximately 60 cm from the participant. Responses were collected by keyboard. An audio recorder was used to document free recall protocols.

Materials

Screening tests

All participants underwent a series of tests to evaluate their reading skills, attentional control, and other related cognitive abilities. The presence of attention disorder symptoms was assessed using the Brown Attention-Deficit Disorder Scales Questionnaire for adults (T. E. Brown, 1996) and the Conjunctive Continuous Performance Task (CCPT; Avisar & Shalev, 2011; Stern & Shalev, 2013). The latter task measured response times and errors in identifying a predefined target stimulus (a red square) among distractors (square, circle, triangle, or star appearing in red, blue, green, or yellow). Word decoding abilities were measured using tests of single-word reading speed and accuracy (Schiff & Kahta, 2009a, 2009b). Nonverbal intelligence was estimated by the Wechsler Intelligence Scale for Children–second Edition (WISC–II) Matrix Reasoning subtest (Wechsler, 1997). Working memory capacity was assessed by the Listening Span test (Conway et al., 2005), which asked the participants to recall the last words of 3–6-sentence sets.

Experimental texts

Three expository texts were used in the present study. The topics of the texts were breastfeeding, the coca plant, and the prophetess from Delphi, and their lengths were 269, 280, and 302 words, respectively. Each text was presented on a single screen using a 16-point Ariel font and double spacing between the text lines. Each text was parsed into clause units that included a main predicate and its "nonclause" arguments (see Appendix A1). An independent group of 20 normal adults evaluated the centrality level of each information unit on a scale from 1 (least central) to 5 (most central). Centrality was defined as a joint function of two criteria: (a) the extent to which an information unit is important for the overall understanding of the text; (b) the extent to which comprehension would be impaired were the information unit to be missing (e.g., Albrecht & O'Brien, 1991; Miller & Keenan, 2009; van den Broek, 1988). Based on these evaluations, 37 units that received the highest centrality scores (*M* = 4.6, *SD* = 0.4) were defined as central units, and 32 units that received the lowest centrality scores (*M* = 1.9, *SD* = 0.6) were defined as peripheral units. The selected units constituted the top and bottom third of the scores received for the units in each text.

To ensure that central and peripheral units did not differ on various verbal dimensions (e.g., word length, word frequency, syntax complexity, etc.), but only on context-based centrality level, a second pretest compared their comprehension time out of context. A group of 23 normal adults was asked to read (silently) the units of the three texts, presented one unit per trial in a mixed order, and judge whether they make sense in Hebrew. Central and peripheral units remained in their original form, whereas the remaining units (39 units) were modified to be nonessential by replacing one word (e.g., "dependence on cocaine also *closet* the user to give up food, drink and other necessary activities"). The pretest results did not reveal a significant difference between the response times observed for the central (*M* = 2,546 ms) and peripheral units

(M = 2,497 ms), $F < 1$. However, a significant interaction was observed between centrality (central, peripheral) and text (breastfeeding, coca, prophetess), $F(2, 44) = 3.93$, $p < .05$, $\eta_p^2 = .15$, indicating that response times were significantly longer for the central units (M = 2,749 ms) than for the peripheral units (M = 2,504 ms) in the coca text, $t(89) = 2.39$, $p < .05$. In exploring the source of this interaction, we found that the difference between the mean length (i.e., number of characters) of central and peripheral units was greatest in the coca text ($M_{central}$ = 47.5 characters; $M_{peripheral}$ = 42.8 characters). To control for this length difference, the response time obtained for each unit was divided by the number of its characters (e.g., Hyönä, Lorch, & Kaakinen, 2002). Using this measurement, we did not find a significant effect of centrality, $F < 1$, nor interaction with text, $F(2, 44) = 2.54$, $p = .09$, $\eta_p^2 = .10$. The differences in response time per character observed for central and peripheral units was not significant in any of the three texts ($ts < 1.64$, $ps > .12$). For consistency, this unit of measurement (i.e., ms/characters) was also adopted in the analyses of reading times in the main study. In this way, we have verified that differences in the processing time of central and peripheral units in the main study could be exclusively attributed to differences in their centrality level.

Experimental tests

Recognition of text ideas was collected by a computerized test built by the E-prime experiment generator software. In this test, the information units comprising the three experimental expository texts were presented in isolation as single sentences. Participants were asked to respond by a key press whether the information included in each unit was mentioned in the text. They were instructed to make their decisions based on the text alone (avoiding their prior knowledge) and to be aware that the differences between the original text ideas and the ideas presented in the recognition test were subtle. Text units that were defined as central and peripheral remained in their original form, whereas the remaining units were slightly modified, to include information not mentioned in the text (e.g., the unit "dependence on cocaine also causes the user to give up food, drink and other necessary activities" was modified to "dependence on cocaine also causes the user to give up food, *but not* drink and other necessary activities" in the recognition test). The various units of the three texts were presented in mixed order.

Centrality estimations in the pretest (described above) and in the main study (see Procedure below) were collected by a computerized Google Forms questionnaire. In this questionnaire, each text was initially presented as a whole in one segment, and was then followed by a list of the parsed text units (see Appendix A1). The units were presented on different lines in the same order as they appeared in the texts. Participants were instructed to estimate the centrality of the various units using a 1–5 centrality scale displayed below each unit.

Procedure

Participants were tested individually in two separate sessions, each lasting about an hour. Each session began with an overview of the overall procedure, with more specific instructions being given prior to each task. In the first session they were tested on the screening tests in the following order: Listening Span, CCPT, Wechsler's Matrix, word reading speed and accuracy, and the Brown questionnaire. In the second session, they performed the experimental tasks in the following order: (a) The participant read the three expository texts successively at their own pace from a computer screen, while their eye movements were recorded. They were instructed to read the texts to summarize their main ideas. (b) After reading the three texts, the participants were asked (in contrast to the primary instructions) to recall as much information as possible from each of the three texts they had just read, in the order they were presented. Recall responses were recorded using an audio recorder, and were transcribed and coded by trained experimenters. (c) Following the recall of the texts, the participants conducted the recognition test. (d) Finally they completed the centrality estimation questionnaire. The presentation order of the texts was counterbalanced across participants, and was identical in the recall, recognition, and centrality estimation tasks. A calibration of the eye-tracking apparatus was conducted before the reading of each text by means of a 13-point calibration grid that covered the entire computer screen.

Results

Screening tests

Table 1 presents the means and standard deviations of the scores obtained for the ADHD and control groups in the various screening tests. Comparing the performance of the two groups revealed that the participants with ADHD received, as expected, a significantly higher score than controls on the Brown questionnaire that measured ADHD symptoms, $t(53) = 8.59$, $p < .001$, $d = 2.35$. Participants with ADHD also exhibited more

Table 1. Means and standard deviations of the scores obtained by the ADHD and control groups in the various screening tests.

	Research groups			
Screening tests	ADHD group	Control group	*p*	Effect size
Brown questionnaire	(18.94) 63.07	(11.18) 26.85	.00	2.35
$\text{CCPT}_{\text{composite}}$[a]	(0.89) 0.21	(0.32) 0.22–	.02	0.64
RT mean (ms)	(102) 365	(58) 348	.45	0.17
RT *SD* (ms)	(58) 107	(31) 81	.03	0.61
Omission errors (%)	(0.04) 0.02	(0.00) 0.00	.04	0.57
Commission errors (%)	(0.49) 0.02	(0.01) 0.01	.13	0.42
Word reading accuracy[a]	(1.07) 0.59–	(0.76) 0.23–	.16	0.39
Word reading speed[a]	(0.89) 0.03	(0.75) 0.28–	.18	0.37
Matrix reasoning[a]	(3.71) 15.18	(2.78) 15.33	.86	0.01
Listening span	(15.15) 40.07	(13.76) 44.51	.26	0.31

Note. ADHD = attention-deficit/hyperactivity disorder; CCPT = Conjunctive Continuous Performance Task; RT = response time. Standard deviations in parentheses.
[a]Standard scores.

omission errors, $t(53) = 2.08$, $p < .05$, $d = 0.57$, and more varied response times, $t(53) = 2.23$, $p < .05$, $d = 0.61$, than those of controls in the CCPT task, although effects were only moderate. Conducting a *t*-test on the averages of the standard scores of all four measurements of the CCPT task (i.e., response time means and standard deviations, and omission and commission errors) indicated an overall inferior performance of the ADHD group as compared to the control group, $t(53) = 2.33$, $p < .05$, $d = 0.64$. The word-reading tests did not reveal significant differences between the two groups on either accuracy, $t(53) = 1.43$, $p = .16$, $d = 0.39$, or speed, $t(53) = 1.36$, $p = .18$, $d = 0.37$. The two groups also did not differ on the nonverbal Matrix, $t < 1$, and Listening Span tests, $t(53) = 1.14$, $p = .26$, $d = 0.31$. Taken together, the screening tests were consistent with the formal diagnoses of the participants in the ADHD group, confirming their attention disorder.

Experimental tests

Means of recall and recognition accuracy proportions, centrality scores, and eye-movement (re)reading times and occurrences, observed for central and peripheral units in each of the three texts, were computed for each participant. In all measurements, data that were more than two standard deviations above or below the mean of the experimental condition were excluded from the analyses (5% of the cases on average). A three-way mixed analysis of variance (ANOVA) was conducted on the means of the various dependent measurements, with centrality (central, peripheral) and text (breast-feeding, coca, prophetess) as within-participants factors and group (ADHD, control) as a between-participants factor. To reduce chances for Type I errors (i.e., false rejection of null hypotheses) as a result of multiple testing of the same sample, we adopted a stricter significance level of $\alpha = .016$. The standard level ($\alpha = .05$) was divided by 3 in accordance with the three independent hypotheses explored in this study (Matsunaga, 2007; Sinclair, Taylor, & Hobbs, 2013; Weber, 2007). For simplicity and conciseness, the Results section reports effects of text only if they interacted with group (see Appendix A2 for the complete set of text effects). Effects of text beyond group indicated linguistic and/or content-based differences between the texts, which do not bear theoretical meaning in this study.

Recall

The ANOVA conducted on recall proportions (i.e., the number of units recalled correctly out of the total number of units in the text) revealed a strong effect of centrality, $F(1, 53) = 200.46$, $p < .001$, $\eta_p^2 = .79$. This effect indicated that recall proportions were higher for the central ($M = .39$) than for the peripheral units ($M = .20$; i.e., centrality effect). A significant Group × Centrality interaction was also obtained, $F(1, 53) = 8.36$, $p < .01$, $\eta_p^2 = .14$, showing a larger centrality effect in the control group ($M = .23$) than in the ADHD group ($M = .18$; see Figure 1, Panel A). Post hoc analyses revealed that the centrality effect was significant for both groups (*F*s > 142.83, *p*s < .001). However, the participants in the control group recalled significantly more central units ($M = .44$) than the participants in the ADHD group ($M = .35$), $F(1, 53) = 8.36$, $p < .01$, $\eta_p^2 = .14$, whereas no significant difference was observed between the groups in the recall proportions of the peripheral units ($M_{\text{control}} = .21$, $M_{\text{ADHD}} = .18$, $F < 1$). The effect of group did not reach the significance level adopted in this study ($p = .046$). These findings demonstrate a centrality deficit in text recall for the participants with

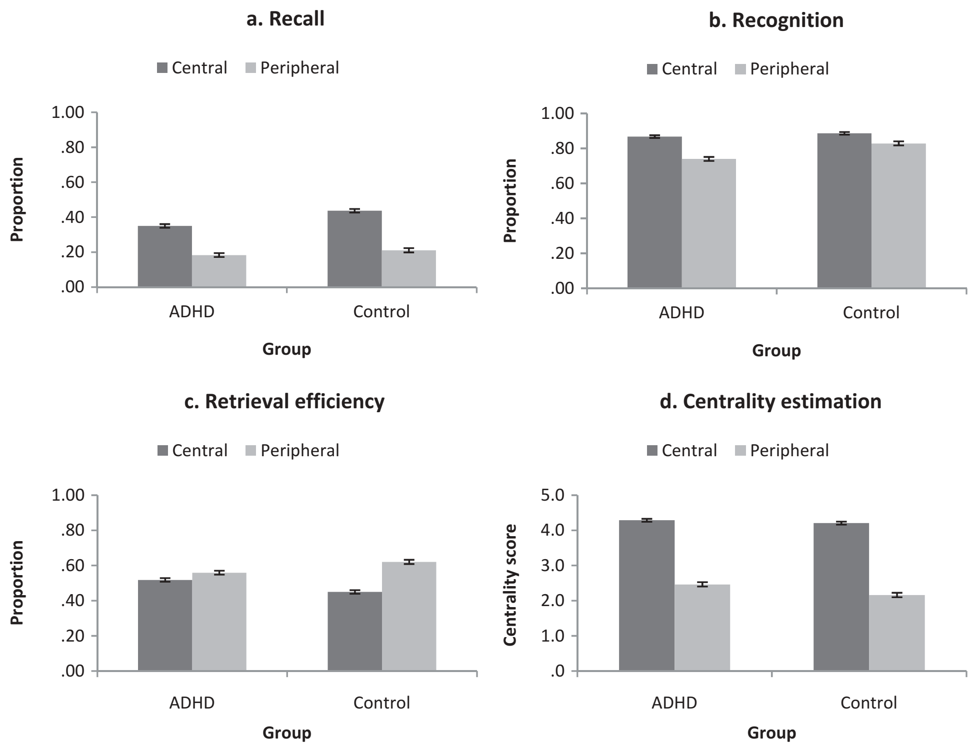

Figure 1. Means of recall proportions, recognition proportions, retrieval efficiency proportions, and centrality estimations obtained for central and peripheral units by the attention-deficit/hyperactivity disorder (ADHD) and control groups. Error bars represent standard errors.

ADHD, as observed in previous studies (e.g., Miller et al., 2013).

Recognition

The ANOVA conducted on recognition accuracy proportions (i.e., the number of old and new units that were correctly recognized as such, out of the total number of units in the text) revealed a strong effect of centrality, $F(1, 53) = 50.00$, $p < .001$, $\eta_p^2 = .48$. This effect indicated that recognition accuracy was higher for the central ($M = .88$) than for the peripheral units ($M = .79$). A significant Group × Centrality interaction was also revealed, $F(1, 53) = 7.10$, $p < .01$, $\eta_p^2 = .12$, demonstrating, in contrast to the recall findings, a larger centrality effect for the ADHD (M = .13) than for the control group ($M = .06$; see Figure 1, Panel B). Post hoc analyses revealed that the centrality effect was significant for both groups (*Fs* > 11.99, *ps* < .01). However, the accuracy of recognizing the *peripheral* units was higher for the control ($M = .83$) than for the ADHD group ($M = .74$), $F(1, 53) = 7.15$, $p < .01$, $\eta_p^2 = .12$, whereas no significant difference was observed between the groups in recognizing the *central* units ($M_{control} = .88$, $M_{ADHD} = .87$, $F < 1$). The effect of group did not reach significance ($p = .036$). These findings indicate a normal centrality effect (i.e., no indication for a centrality deficit) in text recognition for the ADHD group (their centrality effect was even larger than that observed for the control group).

Retrieval efficiency

To compare the retrieval efficiency of the two groups, an additional ANOVA was conducted on the differences computed between the recall and recognition proportions of central and peripheral units in each text. Note that the lower the difference is between recall and recognition performances, the higher the retrieval efficiency of the reader. This ANOVA revealed a strong effect of centrality, $F(1, 53) = 32.76$, $p < .001$, $\eta_p^2 = .38$, indicating a higher efficiency in retrieving the central ($M = .48$) than the peripheral units ($M = .59$). This centrality effect was qualified by a significant interaction with group, $F(1, 53) = 12.30$, $p < .001$, $\eta_p^2 = .19$. Post hoc analyses revealed a strong centrality effect in retrieval efficiency for the control group, $F(1, 26) = 38.75$, $p < .001$, $\eta_p^2 = .60$, but not for the ADHD group, $F(1, 27) = 2.70$, $p = .11$, $\eta_p^2 = .09$ (see Figure 1, Panel C). The effect of group was not significant ($F < 1$). These findings indicate a centrality deficit in text retrieval efficiency for the participants with ADHD, consistent with the retrieval-cues-shortage hypothesis.

Centrality estimation

The ANOVA conducted on the centrality scores assigned to the various units revealed a strong effect of centrality, $F(1, 53) = 674.99$, $p < .001$, $\eta_p^2 = .93$, indicating higher scores for the central ($M = 4.25$) than for the peripheral units ($M = 2.31$; see Figure 1, Panel D). The main effect of group and its interaction with centrality were not significant (Fs < 2.1, ps $> .15$). These findings indicate a normal centrality effect (i.e., no indication of a centrality deficit) in centrality estimation for the ADHD group, contrary to the expectations derived from the poor-centrality-estimation hypothesis.

Eye-movement measurements

Four types of eye-movement data were analyzed: (a) total reading time: the sum of durations of all fixations landed within a text unit; (b) first-pass reading time: the sum of durations of all fixations landed within a text unit before any subsequent unit was fixated on; (c) rereading time: the sum of durations of all fixations landed within a text unit that had already been read once before; (d) rereading occurrence: the number of occurrences a text unit was reread after it was read for the first time. For the first-pass reading time analysis, we excluded all cases in which subsequent text units were read before the target unit (22% of the trials). All measurements were divided by the number of characters in that unit to control for unit length variation (similar to the pretest).

Total reading time

The ANOVA conducted on total reading times revealed a strong effect of centrality, $F(1, 53) = 24.43$, $p < .001$, $\eta_p^2 = .32$. This effect demonstrated longer reading times for central ($M = 51.97$) than for peripheral units ($M = 47.32$). The effect of group ($p = .030$) and the Group × Centrality interaction ($F < 1$) were not significant (see Figure 2, Panel A). These findings do not reveal a centrality deficit in total reading time for the ADHD group.

First-pass reading time

The ANOVA conducted on first-pass reading times revealed a significant effect of centrality, $F(1, 53) = 11.92$, $p < .001$, $\eta_p^2 = .18$, indicating longer first-pass reading times for central ($M = 40.76$) than for peripheral units ($M = 30.41$). The main effect of group and its interaction with centrality were not significant (Fs < 1.5, ps $> .23$; see Figure 2, Panel B). As in the total reading time, no centrality deficit was found for the participants with ADHD in first-pass reading time.

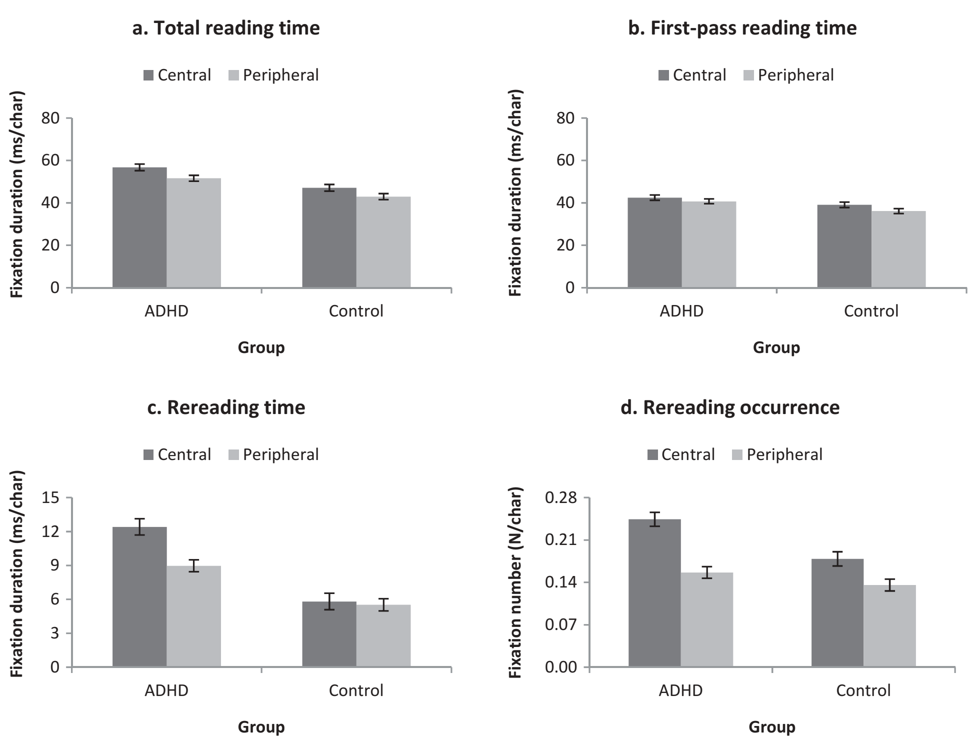

Figure 2. Means of total reading times, first-pass reading times, rereading times, and rereading occurrences obtained for central and peripheral units by the attention-deficit/hyperactivity disorder (ADHD) and control groups. Error bars represent standard errors.

Rereading time

The ANOVA conducted on rereading times revealed a significant effect of group, $F(1, 53) = 9.25$, $p < .01$, $\eta_p^2 = .15$. This effect indicated that rereading times were longer for the ADHD ($M = 10.69$) than for the control group ($M = 5.66$). A significant effect of centrality, $F(1, 53) = 7.25$, $p < .01$, $\eta_p^2 = .12$, indicated that rereading times were longer for central ($M = 9.11$) than for peripheral units ($M = 7.24$). A moderate effect of Group × Centrality interaction was also obtained, $F(1, 53) = 5.11$, $p = .018$, $\eta_p^2 = .09$, approaching the significance level adopted in this study. Planned comparisons revealed that rereading times were significantly longer for central ($M = 12.41$) than for peripheral units ($M = 8.96$) in the ADHD group, $F(1, 27) = 10.56$, $p < .01$, $\eta_p^2 = .28$, but not in the control group, $F < 1$ (see Figure 2, Panel C). Thus, no centrality deficit was found for the ADHD group in rereading time. Moreover, only the ADHD group showed a centrality effect in rereading time.

Rereading occurrence

The ANOVA conducted on rereading occurrences revealed a significant effect of centrality, $F(1, 53) = 14.04$, $p < .001$, $\eta_p^2 = .21$, indicating that rereading occurrences were more frequent toward the central ($M = 0.21$) than the peripheral units ($M = 0.15$). The main effect of group and its interaction with centrality were not significant ($Fs < 3.1$, $ps > .08$; see Figure 2, Panel D). Similar to the other three eye-movement measurements, no centrality deficit was found for the ADHD group in rereading occurrences. Taken together, the eye-movement measurements did not reveal any centrality deficit for the ADHD group, contrary to the expectations derived from the deficient-attention-regulation hypothesis.

Cognitive–verbal skills

To examine the role played by the various cognitive–verbal skills, as assessed by the screening tests, in the centrality effect/deficit observed in the recall test, three sets of multiple regression analyses were conducted on the recall proportions obtained for the entire group of participants and for each group separately (see Table 2). The regression analyses revealed significant or marginally significant unique contributions for working memory capacity in predicting recall proportions of central units, when conducted for both groups ($p < .05$), and for the ADHD group ($p = .06$). When conducted separately for the control group, the regression analysis revealed a significant unique contribution for reading accuracy ($p < .05$) in predicting recall proportions of central units.

Table 2. Results of regression analyses predicting recall proportions of central ideas by the two groups, based on the screening test scores.

	All		ADHD		Control	
	β	p	β	p	β	p
Brown	.25	.07	.09	.62	.01	.99
CCPT	.11	.46	.21	.34	.21	.28
Nonverbal IQ	.08	.56	.18	.43	.15	.46
Reading time	.08	.58	.23	.27	.07	.70
Reading accuracy	.16	.25	.15	.46	.53	.02
Working memory	.33	.03	.45	.06	.16	.41
R^2	.21		.28		.29	

Note. ADHD = attention-deficit/hyperactivity disorder; CCPT = Conjunctive Continuous Performance Task.

Discussion

The present study explored several potential causes that may underlie the centrality deficit observed in text recall by individuals with ADHD. Specifically, we examined whether deficient attention regulation, shortage of retrieval cues, and/or poor centrality estimation of text ideas explain their impaired recall of central ideas after reading. In this study, the centrality deficit was investigated in adult university students with ADHD, who had read expository texts to summarize their main ideas after reading. The present findings replicated (and extended the validity of) the centrality effect and centrality deficit observed in text recall by individuals with ADHD (Flake et al., 2007; Lorch et al., 1999, 2004; Miller et al., 2013). Our participants with ADHD recalled more central ideas than peripheral ones (i.e., centrality effect), albeit fewer than the control participants (i.e., centrality deficit), whereas no difference was observed between the two groups in recalling peripheral ideas. These findings suggest that the centrality deficit in text recall observed in individuals with ADHD is robust and broad, occurring in both children (Lorch et al., 1999; Miller et al., 2013) and university students, who may have developed compensating learning strategies, in reading both narrative (Miller et al., 2013) and expository texts. Moreover, the centrality deficit in this study was observed even though the participants were explicitly encouraged to identify and attend central ideas during reading for the purpose of text summarizing after reading. This finding lessens the possibility that the centrality deficit observed in previous studies (e.g., Lorch et al., 1999, 2004; Miller et al., 2013) was a result of a misinterpretation of the reading tasks used in these studies (i.e., overall comprehension and recall).

More importantly, the present findings illuminated the origin of the centrality deficit found in individuals with ADHD. Our participants with ADHD exhibited a centrality deficit in text recall, although the centrality effects and the processing of central ideas they exhibited in (re)reading (times and occurrences), recognition, and centrality estimation of text ideas were comparable or even greater than those observed for the participants without ADHD. This pattern of results suggests that adult students with ADHD have a specific difficulty in retrieving central ideas that are available in their long-term memory after reading. In terms of our a priori hypotheses, this study provides support for the retrieval-cues-shortage hypothesis of centrality deficit, whereas no evidence was found to support the deficient-attention-regulation and poor-centrality-estimation hypotheses of centrality deficit. Taken together, the present findings illuminated shortcomings as well as strengths of university students with ADHD in processing central information of expository texts. The following sections elaborate further on these negative and positive aspects in text processing by individuals with ADHD.

Text processing shortcomings of individuals with ADHD

The present study demonstrated that the participants with ADHD recalled fewer central ideas than their peers, although they attended, recognized, and identified central ideas to the same extent as their peers. Consistently, the retrieval efficiency measurement, which was computed by subtracting the number of *recalled* ideas from the number of *recognized* ideas, indicated a greater efficiency in retrieving central than in retrieving peripheral ideas (i.e., centrality effect) by the control participants, but not by the participants with ADHD, who showed similar efficiency in retrieving central and peripheral ideas. These findings suggest that individuals with ADHD experience more difficulties than their peers in retrieving central ideas they had successfully identified, attended, and stored in long-term memory during reading. According to previous models (Trabasso & Sperry, 1985; van den Broek, 1988) and hypotheses (Lorch et al., 2007; Miller et al., 2013), this retrieval deficiency is a possible outcome of poor formation of conceptual connections established between text ideas. When a reader (or a listener) attempts to recall text ideas, she or he deliberately and continuously activates information stored in long-term memory, which in turn facilitates ("cues") the activation of connected text ideas via spreading activation processes (Kintsch, 1998; Myers & O'Brien, 1998; Singer & Kintsch, 2001). Thus, it is possible that individuals with ADHD construct a shallow, less connected representation of the text, and therefore benefit from fewer cues in retrieving text ideas, particularly central ones, which, by definition, are more connected to other text ideas than peripheral ideas (Lorch et al., 2007; Miller et al., 2013).

Consistent with this explanation, Long and her colleagues have shown that factors that play a role in the construction of an interconnected, elaborated text representation during reading, such as prior knowledge (Long & Prat, 2002; Long, Prat, Johns, Morris, & Jonathan, 2008; Long, Wilson, Hurley, & Prat, 2006), text coherence (Long et al., 2006), and causal inferences (Long, Johns, & Jonathan, 2012), have a greater effect on recollection memory processes that underlie text recall than on familiarity memory processes that underlie text recognition. Likewise, the formation of deficient text representation by our students with ADHD impaired their recall, but not recognition, of central ideas.

Further support for the retrieval-cues-shortage explanation comes from the regression analysis we conducted on the scores obtained in the screening tests. Similar to previous studies (Miller et al., 2013), this analysis indicated that individual differences in working memory capacity explained a significantly unique portion of the variance observed in recall proportions of central ideas, particularly by the participants with ADHD, over and above the differences observed in the other cognitive–verbal abilities. According to reading comprehension theories (Kintsch, 1998; van den Broek, 2010; Yeari, 2017), working memory supports the formation of connections between text ideas (and prior knowledge) during reading, and therefore has an indirect impact on the amount of retrieval cues available after reading (Lorch et al., 2007; Miller et al., 2013). Oddly, we did not find significant differences in working memory capacity between the groups, possibly because our participants with ADHD were university students who typically have greater capabilities. It is also possible that the indirect effect of working memory on retrieval cues becomes significant when it interacts with another cognitive–verbal deficit, such as attention regulation. To summarize, it is highly possible that poor representation of intertext connections underlies the centrality deficit of individuals with ADHD. Nonetheless, further research is required to examine this option in a more direct manner (e.g., by a think-aloud procedure that directly explores the online formation of intertext connections during reading; Berthiaume et al., 2010). Future work should also address whether the centrality deficit is equally likely to be displayed by all three ADHD subtypes (i.e., the inattentive, hyperactive/impulsive, and combined subtypes). The present and previous diagnoses (e.g., Miller et al., 2013) did not distinguish between the centrality deficit of the different ADHD subtypes, although it is important to match the appropriate remedial training to the relevant subtypes of ADHD.

Text processing strengths of individuals with ADHD

Although the present study was designed to explore the deficits in individuals with ADHD, it also discovered a few text processing skills that remained intact in our university student participants. First, the centrality scoring test revealed that our participants with ADHD were as successful as controls in identifying and distinguishing central and peripheral ideas after reading. Moreover, the eye-movement measurements in this study suggest that our participants with ADHD were as successful as controls in assessing the centrality level also *during* reading. Both groups spend more time in reading the central ideas than the peripheral ideas (although no differences were observed in reading the two types of ideas when they were out of context in the pretest), as would be expected under a neutral reading task and certainly under the summarizing task used in this study (Hyönä & Niemi, 1990; Yeari, 2017; Yeari et al., 2015). These findings suggest that university students with ADHD are capable of identifying central information on-the-fly during reading, and dividing their attention effectively and wisely between central and peripheral ideas in line with the task's requirements. In future research, it would be interesting to examine whether younger individuals with ADHD also possess these skills when they are asked to summarize the text, and whether adults with ADHD naturally prefer the processing of central ideas in reading tasks that do not explicitly encourage doing so (e.g., overall recall). In addition, more research is required to explore the type of cues that individuals with ADHD use to identify central information during and after reading, assuming that the number of intertext connections does not support this ability, as in normal readers.

A second strength that the participants with ADHD exhibited in their text processing relates to the time they invested to *reread* central ideas. Interestingly, the present findings indicated that only the participants with ADHD invested more time in rereading central ideas than peripheral ones. This finding may suggest that our adult students with ADHD have developed reading strategies to compensate for their difficulties in sustaining sufficient attention to central ideas when being encountered for the first time during reading. Moreover, this finding shows that the participants with ADHD could hold and pursue the goal derived from their reading task (i.e., summarizing), and select and implement appropriate strategies to attain this goal. These encouraging findings suggest that the participants with ADHD were aware of the task requirements, of their difficulties, and of the reading strategies required to cope with them. Moreover, comparing their rereading time and recognition accuracy of the central and peripheral ideas implies that the rereading strategy employed by the participants with ADHD was effective in encoding and storing text ideas in long-term memory. The extra time the participants with ADHD invested to reread the central ideas seems to be effective in comparing their recognition performance to that of controls, because when they did not do so in rereading the peripheral ideas, their recognition performance was lower than that of controls.

Nonetheless, the rereading strategy adopted by the participants with ADHD was not effective in enhancing the recall of central ideas. Presumably, the extra time devoted to store central ideas in memory involved shallow encoding strategies, such as repetition and memorization techniques, rather than deep encoding strategies, such as connecting central ideas with other text ideas and/or prior knowledge (Linderholm & van den Broek, 2002; King, 2007 McCrudden, Schraw, & Hartley, 2006). This assumption receives some support from correlations that we computed between the number of rereading occurrences and recall proportions of central ideas observed in each text for each participant ($N_{(\text{participant}\times\text{text})} = 84$). These analyses revealed a significant positive correlation for the control participants ($r = .25$, $p < .05$), but not for the participants with ADHD ($r = -.13$, $p < .05$). These correlations suggest that rereading occurrences were effective in enhancing the recall of central ideas only when they were employed by the control participants.

Concluding remarks

The present study sheds light on the origin of the centrality deficit observed in individuals with ADHD in text recall. Apparently, adult students with ADHD have difficulties in recalling central ideas that they adequately attended during reading and successfully identified and recognized after reading. Moreover, the extent that the participants with ADHD recalled central ideas was uniquely associated with their working memory capacity, which plays a central role in establishing connections between text ideas during reading (Yeari, 2017). These findings, in conjunction with existing theoretical models (van den Broek, 1988) and hypotheses (Lorch et al., 2007; Miller et al., 2013), suggest that individuals with ADHD have specific difficulties in retrieving central ideas that are available in their long-term memory, presumably due to inadequate construction of intertext connections during reading, which act as retrieval cues after reading. These conclusions have important implications for development of remedial programs designed to improve text processing and recall for individuals with ADHD. These programs should instruct individuals with ADHD how to identify and construct conceptual connections between text ideas during reading under limited resources of working memory (e.g., text segmentation, online questioning). Instructors should clarify and emphasize the importance of intertext connections to text comprehension and memory, and continually encourage individuals with ADHD to connect, extend, and elaborate text information during reading. Future studies that would examine the effect of such programs on text recall by individuals with ADHD could provide further support for the retrieval-cues-shortage hypothesis supported in this study.

Notes

1. Centrality deficit and centrality effect were originally termed to describe differences in *recalling* central and peripheral ideas (Miller & Keenan, 2009). In this paper, we applied these terms to describe differences in any type of processing of text ideas. Specifically, these terms were used to describe differences in (re)reading, recognition, and centrality estimation (in addition to recall) of central and peripheral ideas.
2. Centrality deficit in recall was observed only in recalling *central* ideas (Miller et al., 2013). However, it was possible that in other types of processing, differences in the size of centrality effect are more indicative than differences in the processing of central ideas alone. For instance, reading times of *central* ideas are less indicative for assessing attention regulation, because individuals with ADHD are generally slower than controls in reading texts. Therefore, a slower reading of central ideas by the ADHD group may incorrectly indicate efficient attention regulation. In this case, the difference between the reading times of central and peripheral ideas (i.e., centrality effect size) is more appropriate for assessing the quality of attention regulation.

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Appendix A1

Experimental texts divided into idea units. Underlined are the central units and in italics are the peripheral units. The remaining units are those that received intermediate centrality scores and were not included in the analyses.

The coca plant

- The coca plant is a common bush in South America.
- *This is a domesticated bush,*
- *which reaches a height of 2–3 meters.*
- <u>This plant has a variety of uses.</u>
- Some of which were widespread in the past
- and some are common today.
- <u>In ancient times, coca leaves were used mainly as a pain medication.</u>
- <u>Chewing the coca leaves increased the sensitivity threshold for the sufferer.</u>
- However, the sufferer did not reach a state of unconsciousness
- or loss of sense of touch.
- <u>Also, coca leaves alleviate headaches and dizziness.</u>
- These pains were caused by presence in the oxygen-low environment of the high Andes peaks.
- *Since the peaks of the mountains in the Andes can reach as high as 7,000 meters.*
- <u>The Andean population also used coca leaves as a nutritional supplement.</u>
- <u>Coca leaves contain a large amount of proteins and vitamins,</u>
- and therefore the Andean people often consumed them.
- *In addition to the coca leaves, the Andean population also consumed other food products, such as quinoa.*
- *These plants are able to grow in the harsh conditions of the Andes.*
- <u>The coca plant also had symbolic and religious meanings among the Andean population.</u>
- Researchers believe the Andes believed they had to chew coca leaves when performing religious ceremonies,
- so that their prayers would be answered.
- *These ceremonies were aimed at local gods,*
- *whose identity was different from region to region.*
- Coca leaves also have uses today.
- <u>It was found that they contain chemicals that have a strong effect on the human brain.</u>
- <u>These substances include alkaloids and cocaine.</u>
- This substance is produced from the dangerous drug cocaine.
- *In 1884, cocaine was isolated from the coca plant.*
- <u>Since then it has been associated with the euphoria it evokes.</u>
- Dependence on cocaine also causes the user to give up food, drink and other necessary activities.
- <u>Other materials found in Coca are used, among other things, for the production of the Coca-Cola beverage.</u>
- *The drink was invented by a pharmacist named John S. Pemberton in 1886.*
- Today it is the best-selling drink in the United States.
- Coca-Cola has a lot of political power,
- and has a great impact on the American economy.

Breastfeeding

- <u>Breastfeeding is the feeding method characterizing human babies.</u>
- <u>Mother's milk contains all the nutrients the baby needs.</u>
- <u>The mother's milk also contains antibodies</u>
- <u>helping the baby during the first months of his life,</u>
- in which his immune system is not strong enough.
- *These antibodies are protein molecules*
- *belonging to the immune system.*
- <u>The composition of breast milk varies according to the baby's needs.</u>
- For example, the longer the breastfeeding period, the more fatty the milk.
- As a result, the older baby gets more calories.
- The mother's nutritional status has little effect on milk volume,
- unless it is in a state of particularly severe malnutrition.
- *This situation is not common in developed countries,*
- *due to the large number of existing food sources.*
- <u>The process of milk production begins in the mother during pregnancy,</u>
- as a result of the secretion of the hormone prolactin.
- *This hormone is secreted by the frontal lobe of the pituitary gland.*
- In the first weeks after birth, the body produces more milk than is necessary,
- *so many women experience a sense of congestion.*
- <u>A few weeks after birth, the body learns to produce the amount of milk needed for the baby,</u>
- and milk production is balanced.
- <u>The milk continues to be produced as long as the baby continues to nurse.</u>
- The positive feedback mechanism is responsible for this increased production.
- *Positive feedback is a situation in which information about the outcome affects the frequency of the appearance of an identical event.*
- When the number of lactations decreases, hormone production and secretion of prolactin decreases,
- so the milk production in the mother is weakened accordingly.
- There are cases in which a mother cannot breastfeed,
- *or cases in which the mother prefers not to breastfeed for various reasons.*

- In these cases, the mother uses infant formula.
- *These substitutes are based on cow's milk or soy milk.*
- *They are rich in essential fatty acids from omega-3 and omega-6,*
- which are an essential component of brain cells and the central nervous system.
- *Milk substitutes are often marketed to consumers as powder.*
- *Boiled water must be added to this powder,*
- *and brought to an appropriate temperature to feed the baby.*

The prophetess from Delphi

- In ancient Greece, they would consult with the "Pythia," prophetess of the gods, before fateful decisions.
- *The role of the Pythia was filled by a woman,*
- who sat in the temple of Apollo in Delphi
- and delivered messages to people from the gods.
- *The city name Delphi comes from the word Delphis in ancient Greek,*
- *which means a womb.*
- Over the years there has been debate about the factors that enabled the "prophecies" of the Pythia.
- Plutarch, a first-century historian, explained the prophecy of the Pythia in that the prophetess sat next to a crevice,
- from which gas vapors arose
- which made her hallucinate
- and deliver the word of God.
- This explanation was even reinforced after an ancient artifact was found in Delphi
- bearing a painting of the Pythia.
- This painting is consistent with the image described by Plutarch.
- *This explanation did not undermine Plutarch's belief in the power of the gods,*
- *despite the fact that according to his teachings they use our worldly materials*
- *in order to implement their plans.*
- *Later Plutarch served as one of the two priests in Delphi.*
- At the beginning of the twentieth century, an English scholar named Oppé took issue with Plutarch's explanation.
- Oppé claimed that Delphi never had a crevice,
- and that there is no natural gas
- which can create the situation described in the ancient descriptions.
- He also added that there are ancient testimonies describing the prophetess sitting calmly on a high chair
- *and singing.*
- On the other hand, Plutarch's description included madness,
- which sometimes ended with the death of the prophetess.
- Other researchers supported Oppé's position
- as they found no opening in the ground in the area of the Temple of Apollo.
- *These researchers used various means, such as: various excavation tools, magnifying devices, and interviews with elders.*
- In the 1980s an extensive geological survey was conducted in Greece
- which again changed the attitude to Pythia.
- One of the geologists found evidence of a geological fault at the site,
- which led to the renewal of archeological excavations.
- Below the temple's floor level a sunken room was found.
- In addition, an underground system of tunnels was found
- into which spring water is drained.
- These resulted from the encounter of two large geological faults,
- *apparently created by tectonic activity in the area.*
- In the water were found products of ethylene gas
- which directly affects one's consciousness.
- This gas may create a trance state
- and even cause death.

Appendix A2

Main effects of Text

Main effects and interactions of text.

Test	Effect	*F*	*p*	η_p^2
Recall	Text*	5.495	.005	.094
	Text × Group	0.868	.423	.016
	Text × Centrality*	14.331	.000	.213
	Text × Group × Centrality	0.429	.652	.008
Recognition	Text	0.904	.408	.017
	Text × Group	0.098	.906	.002
	Text × Centrality	1.467	.235	.027
	Text × Group × Centrality	0.369	.692	.007
Retrieval efficiency	Text	1.373	.258	.025
	Text × Group	0.590	.556	.011
	Text × Centrality*	15.113	.000	.222
	Text × Group × Centrality	0.881	.417	.016
Centrality estimation	Text*	5.997	.003	.102
	Text × Group	1.336	.267	.025
	Text × Centrality*	8.315	.000	.136
	Text × Group × Centrality	0.894	.412	.017
Total reading time	Text*	5.457	.006	.093
	Text × Group	3.410	.037	.060
	Text × Centrality	2.115	.126	.038
	Text × Group × Centrality	0.684	.507	.013
First-pass reading	Text	3.015	.053	.054
	Text × Group	3.015	.088	.054
	Text × Centrality	3.389	.037	.060
	Text × Group × Centrality	0.755	.472	.014
Rereading time	Text	2.266	.109	.041
	Text × Group	1.035	.359	.019
	Text × Centrality	0.570	.567	.011
	Text × Group × Centrality	0.422	.657	.008
Rereading occurrence	Text	3.282	.041	.058
	Text × Group	3.100	.049	.055
	Text × Centrality	3.084	.050	.055
	Text × Group × Centrality	0.921	.401	.017

*These effects are significant at α level of .016.

Means and contrasts of significant main effects of text.

Test	Coca (a)	Breast-feeding (b)	Prophetess (c)	Significant contrasts*
Recall	0.26	0.35	0.25	b > a, b > c
Centrality estimation	3.26	3.35	3.41	c > a
Total reading time	46.72	49.36	52.66	c > a

*These contrasts are significant at α level of .016.

Means and contrasts of significant Text × Centrality interactions.

	Coca (a)		Breast-feeding (b)		Prophetess (c)		
Test	Central	Peripheral	Central	Peripheral	Central	Peripheral	Significant contrasts*
Recall	0.36	0.16	0.38	0.28	0.43	0.14	a, b, c
Retrieval efficiency	0.51	0.59	0.50	0.51	0.43	0.66	a, c
Centrality estimation	4.2	2.1	4.1	2.4	4.4	2.4	a, b, c

*The difference between central and peripheral units in these texts is significant at α level of .016.