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What information should I look for again? Attentional difficulties distracts reading of task assignments



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ABSTRACT

This large-scale eye-movement study ($N = 164$) investigated how students read short task assignments to complete information search problems and how their cognitive resources are associated with this reading behavior. These cognitive resources include information searching subskills, prior knowledge, verbal memory, reading fluency, and attentional difficulties. In this study, the task assignments consisted of four sentences. The first and last sentences provided context, while the second or third sentence was the relevant or irrelevant sentence under investigation. The results of a linear mixed-model and latent change score analyses showed the ubiquitous influence of reading fluency on first-pass eye movement measures, and the effects of sentence relevancy on making more and longer reinspections and look-backs to the relevant than irrelevant sentence. In addition, the look-backs to the relevant sentence were associated with better information search subskills. Students with attentional difficulties made substantially fewer look-backs specifically to the relevant sentence. These results provide evidence that selective look-backs are used as an important index of comprehension monitoring independent of reading fluency. In this framework, slow reading fluency was found to be associated with laborious decoding but with intact comprehension monitoring, whereas attention difficulty was associated with intact decoding but with deficiency in comprehension monitoring.

1. Introduction

In the school context, a purposeful reading activity usually starts with task assignment, the proper understanding of which is assumed to be crucial for the entire reading activity (Rouet et al., 2017). For instance, the *information need* (Taylor, 1968) derived from search prompts is assumed to guide readers to develop productive search queries, evaluate and select relevant search results, and locate and focus on relevant information on the corresponding webpages (Belkin, 2000; Bilal & Kirby, 2002; Leu, Kinzer, Coiro, & Cammack, 2004). While qualitative evidence has suggested that there are large individual differences in interpreting broadly defined essay task assignments (Nelson, 1990), no previous study has investigated how students read simple and unambiguous task assignments, such as Internet search prompts (Zawilinski et al., 2007), or the consequences it has for subsequent reading performance.

Understanding task assignments may be especially challenging for

students with reading and attention deficits, who have been found to also show subtle reading comprehension deficits (Ghelani, Sidhu, Jain, & Tannock, 2004; Martinussen & Mackenzie, 2015; Miller et al., 2013; Sesma, Mahone, Levine, Eason, & Cutting, 2009). However, little is known about how these students cope with purposeful reading in general and new digital information literacy demands in particular (Ben-Yehudah et al., 2018). Nonetheless, because of the executive challenges in reading non-linear texts, increased difficulty is to be expected (Coiro, 2011; Savolainen, 2002; Taboada & Guthrie, 2006).

For these reasons, we investigated how students with and without reading and attentional difficulties read short task assignments containing an important sentence and an unimportant sentence in an informational task that simulated an information search on the Internet as well as the possible implications of this assignment on task performance.

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1.1. Cognitive basis of reading comprehension and learning difficulties

Reading comprehension is built on the proper interplay of several cognitive functions (Bohn-Gettler & Kendeou, 2014; Miller et al., 2013). Fluent decoding skills free an individual's attentional working memory resources for comprehension (Verhoeven & Van Leeuwe, 2008). Prior knowledge (Kendeou & van den Broek, 2007), vocabulary (Calvo, Estevez, & Dowens, 2003), and nonverbal reasoning abilities (Tiu Jr, Thompson, & Lewis, 2003) are important resources for making semantic interpretations and connections between different concepts in a text. The relevant information is stored and further processed in the working memory (Sesma et al., 2009; Swanson, Zheng, & Jerman, 2009). Executive functions regulate the individual's attention to several objects over a lengthy period (Locascio, Mahone, Eason, & Cutting, 2010; McVay & Kane, 2012).

Developmental dyslexia affects 4% to 9% of students (see Ben-Yehudah et al., 2018). It is characterized by inaccurate, slow, and dysfluent reading at the word level despite adequate reading instruction and normal intelligence (DSM-V, APA, 2013). Laborious decoding often impairs reading comprehension (Kirby & Savage, 2008). In addition, dyslexia may be associated with additional comorbid subtle deficiencies in working memory (Moll, Gobel, Gooch, Landerl, & Snowling, 2016), and executive function (Locascio et al., 2010).

Attention deficit and hyperactivity disorder (ADHD) is characterized by difficulties with inattention, impulsivity, and hyperactivity (DSM-V, APA, 2013). It affects an estimated 5% to 7% of the population (Willcutt et al., 2010). Children with ADHD often struggle in school, and their academic difficulties extend from childhood to college (Lewandowski, Gathje, Lovett, & Gordon, 2013). Miller et al. (2013) showed that after controlling for word reading abilities, attention deficit still predicted poorer recall of the central ideas of a text. However, this effect is mediated by working memory deficits (Friedman, Rapport, Raiker, Orban, & Eckrich, 2017; Sesma et al., 2009), especially in the verbal domain (Koefer, Rapport, Bolden, Sarver, & Raiker, 2009; Pimperton & Nation, 2010). New evidence has suggested that attention deficits are also associated with impairments in metacognition, especially in planning (Alvarado, Puente, Jiménez, & Arrebillaga, 2011; Pezzica, Vezzani, & Pinto, 2018) and comprehension monitoring (Berthiaume, Lorch, & Milich, 2010).

The comorbidity between dyslexia and ADHD is around 30% (Germanò, Gagliano, & Curatolo, 2010; Landerl & Moll, 2010). This comorbidity is associated with a particularly poor prognosis for future academic and behavioral difficulties (DuPaul, Morgan, Farkas, Hillemeier, & Maczuga, 2016). Reading and attention disabilities also share common cognitive deficiencies in the working memory (Tiffin-Richards, Hasselhorn, Woerner, Rothenberger, & Banaschewski, 2008) and in the executive function (Locascio et al., 2010).

1.2. Purposeful reading

Generally, the ability to identify and focus on the relevant part of text for the required purpose of reading (McCrudden & Schraw, 2007) depends on the reader's metacognitive comprehension monitoring abilities (Rouet, Britt, & Durik, 2017), and it takes place typically by the conscious rereading of important parts of text (Cerdán, Gilabert, & Vidal-Abarca, 2011; Hyönä & Nurminen, 2006). The purpose of reading also guides thinking during reading. Think-aloud studies have shown that a specific goal, such as in the present study, makes thinking during reading more focused (i.e., monitoring, repeating, and paraphrasing) and less inferential (i.e., elaborating and predicting) compared to reading for general comprehension (Tilstra & McMaster, 2013; see also van den Broek, Lorch, Linderholm, & Gustafson, 2001).

At the level of cognitive schemas, according to the theory of purposeful reading (RESOLV model; Britt, Rouet, & Durik, 2017; Rouet et al., 2017), readers implicitly or partly consciously construct a context model, a task model, and a text model. The context is understood as a

set of reader qualities and environmental cues that affect the construction of a highly specific task model, which is used to guide the actual reading strategies and behavior (i.e., to represent the text). The task model consists of goals, plans, and values. The construction of the task model is assumed to be affected by limited processing resources, feelings-of-knowledge (FOKE), benefit-cost analyses, and decision thresholds for different actions. These processes govern evaluations, such as the differentiation of relevant from irrelevant information, noticing the need to reread a certain part of the text, and realizing when the reading goal is satisfied. Crucially, RESOLV predicts that students make minimal yet sufficient task-elaboration (Martinez, Vidal-Abarca, Gil, and Gilabert, 2009) and that the task model constructed has implications for subsequent reading performance.

Thus, in reading task assignments, the students' existing schema knowledge becomes activated through the situation (a fictional thought: "This is a research experiment, so I should do the best I can") and specific parts of the text (e.g., "Find information about..."). Then readers go through several implicit evaluations, such as FOKE (e.g., "Coral reefs are sea environment full of life."), benefit-cost analyses to calibrate their effort level (e.g., "These tasks will be many so I should work efficiently to avoid spending whole day in this lab."), and strategic approaches to the task at hand (e.g., "I repeat the objective-sentence to remember it."). Although the executive demands for reading simple task assignments are rather low, students with attention deficits may nonetheless show aberrant purposeful reading behavior (e.g., "I read instructions fast to get to the real task."). Moreover, low reading fluency may alter the dynamics of purposeful reading, such as by leading to the increased focus on relevant sentences in order to minimize the overall amount of reading (e.g., "I'll search for the objective-sentence and read that only.>").

1.3. Eye movements reflect reading comprehension processes

While the quality of the mental model of a text can be assessed using various outcome measures of reading comprehension, the only non-intrusive way to study the construction of a mental model is to record the readers' eye movements (Rayner, 1998). Sentence-level eye movements in particular have been found to be instrumental in studying reading comprehension processes (Hyönä & Nurminen, 2006).

Progressive fixations mainly reflect the efficiency of decoding a novel text (Rayner, 1998), yet small effects of text relevancy or reading purpose have also been found in some studies. For example, Kaakinen, Lehtola, and Paattilampi (2015) found that second graders slowed their progressive fixation durations (approximately 6 ms per word) when they were reading to answer a question compared to reading for general comprehension. However, this task-effect was present only in the later measures of older students and adults. In another study, primary school students showed a text relevancy effect in first-pass measures, including a 5-ms prolongation of the first fixation duration per word for task-relevant vs. irrelevant nouns in the text (Schoot, Vashbinder, Horsley, & Lieshout, 2008). This effect, however, did not correlate with reading comprehension, suggesting that it was merely reflective of the detection of relevant information, not its complete processing. de Leeuw, Segers, and Verhoeven (2016a, 2016b) found that in Dutch children in the fifth grade, shorter gaze duration for all words was associated with better vocabulary and working memory, while longer gaze duration for words in paragraph headings and first sentences specifically was associated with better reading comprehension. Finally, a few studies in adults have documented shorter progressive fixation durations for readers with high prior knowledge on the topic (Calvo, 2005; Kaakinen, Hyönä, & Keenan, 2003).

Reinspections are regressive eye movements made during the first-pass reading of a sentence. Slow readers make reinspections for decoding purposes, whereas high comprehenders make reinspections in order to construct a more coherent representation of the entire text (de Leeuw et al., 2016a, 2016b; Kaakinen et al., 2015; Kender &

Rubenstein, 1977; Schoot et al., 2008; Yeari, van den Broek, & Oudega, 2015). As a sign of more effortful processing, second-grade children made more reinspections (although of similar duration) in reading to answer a question than in reading for comprehension. In contrast, in adults, reading to answer questions facilitated reading, which led to fewer and shorter reinspections than in reading for comprehension (Kaakinen et al., 2015). Burton and Daneman (2007) reported that metacognitively proficient adult readers with low working memory capability increased their reinspection durations for task-relevant portions of text. In summary, reinspections seem to reflect broadly different types of processing challenges stemming either from difficulties in word recognition, or semantic integration between words, but also due to adoption of different reading strategies depending on the reading purpose.

Rereadings or look-backs are thought to reflect a reader's conscious and strategic comprehension monitoring processes (for a review, see Hyönä & Nurminen, 2006; Schotter, Tran, & Rayner, 2014). This process is strongly modulated by the goal of the reading activity. For example, reading for study vs. entertainment (Yeari et al., 2015) or for questions vs. general comprehension (Kaakinen et al., 2015) increased the number of look-backs during reading. In addition, look-backs to a relevant part of the text were associated with better reading comprehension performance (Hyönä, Lorch, & Kaakinen, 2002; Hyönä & Nurminen, 2006). However, Kaakinen et al. (2003) showed that good working memory and prior knowledge of the topic enabled an individual to read a task-relevant portion of the text without devoting extra processing time to it. In a similar vein, Calvo (2005) showed that readers with high vocabulary, access speed, and working memory made fewer look-backs when they read inferential sentences. These findings point to the strategic "on-demand" nature of look-backs, which depends on the quality of both the text and the reader.

Taken together, the decoding of linguistic information is reflected by progressive fixation duration and immediate responsiveness to initial comprehension or decoding challenges by reinspection. Late comprehension processes are indexed by look-backs, which reflect a strategic effort to monitor, resolve, or strengthen an individual's representation of certain parts of the text in relation to the purpose of reading. Reinspections and look-backs are typically beneficial for reading comprehension, yet they are initiated on an "on-demand" basis, depending on several reader and task-related factors.

1.4. How do reading and attention difficulties disturb the reading process?

While sentence-level eye-movement measures have not been previously studied in learning-disabled populations, it is well known that developmental dyslexia is associated with longer fixation durations and higher numbers of fixations (e.g., Hautala, Hyönä, Aro, & Lyytinen, 2011), shorter saccadic amplitudes during reading, and more reinspections (de Leeuw et al., 2016a, 2016b). These are all manifestations of poor reading fluency and of word decoding problems in particular. Concerning strategic eye movements during reading, de Leeuw et al. (2016a, 2016b) reported that in fourth grade children, better decoding skills was associated with more regressions specifically from a sentence's final words, whereas slower decoders showed longer regression path durations from the final sentences of a paragraph. Although the authors did not interpret these complex interactions, they may have various causes. For example, on one hand, slow decoding speed allows more time for the semantic integration of the words in a sentence. On the other hand, longer amounts of time spent on reading may also result in the memory "leakage" of distant content, which may be recovered by look-backs.

We were able to find only two studies on ADHD populations concerning eye movements during reading. Thaler et al. (2009) reported that students with comorbid attention deficit and dyslexia read words with fewer fixations than students with dyslexia only, which led to more errors in reading. In contrast, Deans, O'Laughlin, Brubaker, Gay,

and Krug (2010) reported that children with attention deficit aged 6 to 12 years exhibited more regressions and vertical saccades during reading.

In summary, there is some evidence of slightly altered eye movement dynamics in purposeful reading due to slow decoding speed, but no previous study has focused on how attentional problems may disturb high-level reading processes.

1.5. The present study

To study how students with and without reading and attentional difficulties read simple four-sentence task assignments for an informational task, we recorded their eye movements. Based on this reading, the students needed to select an appropriate search query, a search result, and after repetition of a task objective, to find and report an answer from a static webpage. Although our tasks were not designed to stress prior knowledge and verbal memory, these known predictors of a reader's eye movements and literacy performance were also included. A self-report measure of prior knowledge will be used in order to reflect the theoretical notion that readers base their decisions on their feelings of knowing rather than their "real" prior knowledge (Britt et al., 2017). The following research questions with associated hypotheses were posed:

RQ1. Which eye-movement measures reflect purposeful reading processes that are operationalized as the difference in reading task-relevant vs. irrelevant sentences?

The difference may already be present in progressive fixations, but the effect should be pronounced in the probability and duration of reinspections and look-backs (Kaakinen et al., 2015; Schoot et al., 2008), or it should appear only in look-backs (Yeari et al., 2015).

RQ2. How do cognitive skills contribute to purposeful and basic reading processes?

Reading fluency is expected to dominate first-pass reading measures. In addition, higher FOKE may facilitate the initial reading of sentences, resulting in overall faster progressive fixation durations and fewer and shorter reinspections (Calvo, 2005; Kaakinen et al., 2003). More frequent and longer reinspections and look-backs at the relevant sentence (Kaakinen et al., 2015; Schoot et al., 2008; Yeari et al., 2015) should lead to a more elaborate task model and thus to better information searching performance (Britt et al., 2017). Limited working memory should be associated with an increased number of look-backs to relevant sentence because the reader may rehearse the relevant sentence (Burton & Daneman, 2007).

RQ3. How do attentional difficulties interfere with purposeful reading processes?

Because of their difficulties in metacognitive comprehension monitoring (Miller et al., 2013), readers with attention difficulties are expected to make fewer look-backs to task-relevant sentences. Alternatively, if they have intact comprehension monitoring abilities but impaired verbal memory, they should make more look-backs and reinspections to relevant sentences. Finally, if they have intact comprehension monitoring and verbal memory but difficulties in relevancy detection, they may exhibit fewer or more reinspections and look-backs in general.

2. Methods

2.1. Participants

The participants were 164 sixth-grade primary school students (age $M = 12$ years 4.2 months, $SD = 3.7$ months; 98 boys, 66 girls) in central Finland with normal or corrected-to-normal vision. The eye-tracking measurement failed in three additional students, whose data were

excluded from the analysis. The students were invited to participate in the study based on the following screening assessments, which were conducted during a large-scale classroom study: reading skill, attentional functioning, and nonverbal IQ performance.

Reading skill was assessed using three separate tasks: a word identification task (Lindeman, 1998), a pseudo-word text reading (Eklund, Torppa, Aro, Leppänen, & Lyytinen, 2015), and a word-chain segmentation test (Holopainen, Kairaluoma, Nevala, Ahonen, & Aro, 2004). It should be noted that both lexical and word decoding processes are important in reading Finnish (Eklund et al., 2015). The reading fluency factor was extracted from these three tests by principal axis factoring with a promax rotation (SPSS). All students below the 15th percentile for reading fluency were invited to participate in the study.

Attentional functioning was assessed using a 55-item attention deficit questionnaire that was designed to be completed by the teachers (Klenberg, Jämsä, Häyriinen, & Korkman, 2010). Higher scores indicated more attentional problems. All students who scored higher than the 75th standardized percentile were invited to participate in the study.

Students with nonverbal reasoning performance (a 15-min, 30-item version of Raven matrices; Raven, Court, & Raven, 1992) below the seventh percentile in the classroom sample were not invited to participate in this study. However, randomly selected students without attentional or reading difficulties who exceeded this criterion were invited to participate (see Table 1 for the number of students who fulfilled the selection criteria). In accordance with the Declaration of Helsinki, we obtained written consent from all students and their caregivers before the study. Ethical approval for this study was received from the Ethical Board of the University of Jyväskylä.

2.2. Task and materials

2.2.1. Verbal memory

The digit span test in the Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2010) requires students to repeat a list of digits spoken by an instructor in the order or the reverse order that it was presented. The former mode stresses short-term memory, and the latter mode stresses working memory in children (Alloway, Gathercole, & Pickering, 2006; St Clair-Thompson, 2010). The list consists of two to nine items in increasing order with two trials for each stimulus number. The task was discontinued after a mistake of a given length in both trials. The score for the correct answers (maximum score of 32) was used as the outcome score. According to the test manual, Cronbach's alpha reliability was 0.63.

2.2.2. Prior knowledge

The information search tasks that were designed were likely not in a sixth grader's prior knowledge, which was confirmed by the results of a self-evaluation questionnaire of feelings of knowing that was completed before the experiment. It included questions such as "How much do you know about the threats to coral reefs?" The answer choices were as follows: 1) I know nothing (38.1% of responses); 2) I know very little

(30.5% of responses); 3) I know a little (20.8% of responses); 4) I know something (9.4% of responses); 5) I know a lot about the subject (1.3% of responses). Because of the small number of high prior-knowledge responses, categories 3 through 5 were combined to achieve an evenly distributed three-category scale. Reliability across the 10 tasks was $\alpha = 0.68$. In the analyses prior knowledge is handled as a trial-level predictor.

2.2.3. Information search experiment

The students completed 10 tasks that simulated searching for information on the Internet without a time-limit. Each task consisted a sequence of subtasks: 1) reading a four-line text for the task assignment; 2) selecting a search query among five alternatives; 3) selecting a search result among four alternatives; 4) reading a static webpage in which the answer was located at either the beginning or the end of a relevantly-titled paragraph; 5) reporting the answer verbally to a research assistant after leaving the webpage screen. Short instruction screens guided the students through the sequence (e.g., "Good work. Next choose the most appropriate search query for the given information search problem."). To ensure that even the lowest-performing students could complete the tasks, the critical task assignment sentence was shown again by an instruction screen immediately prior to entering the webpage. To provide some thematic continuation in the lengthy experiment, two successive tasks always shared a common theme (see Appendix A). Only the eye movements during the first subtask (i.e., the task assignment screen) are investigated in the present paper.

2.2.4. Information search subskills score

For each of the information search problems, the students received one point for selecting the best search query term, one point for selecting the best search result, and one point for correctly reporting the answer verbally to the research assistant after each information search task. The verbal answers were recorded, transcribed to the text, and scored according to predefined criteria for accurate responses. For example, in the task assignment presented in Fig. 1, the students needed to express two ideas presented on the webpage: miners took Indians' land, and many Indians were killed. The interrater reliability of the scores of the verbal responses was high ($\alpha = 0.950$). Because of the small number of zero scores, these values were included in the score 1 category. Thus, the final scale had three levels: low (20% of responses), medium (43.5% of responses), and high (36.6% of responses). The reliability of this summary scale across the 10 tasks was $\alpha = 0.707$. In the analyses, the performance of the information search was handled as a trial-level predictor.

2.2.5. Task assignment subtask

The task assignment screen contained four sentences that were presented on separate lines (see Fig. 1 and Appendix A for all the texts with their English translations). The first and fourth sentences provided a context while the relevant (task objective) and irrelevant yet context-appropriate sentences were presented in counterbalanced positions on lines two and three. The relevant and irrelevant sentences had uniform

Table 1
Descriptive results of cognitive measures in groups of students fulfilling the inclusion criteria.

Measure	Control (C) N = 87		Attentional difficulty (AD) N = 28		Reading difficulty (RD) N = 23		Comorbid (CM) N = 24		Comparisons
	M	SD	M	SD	M	SD	M	SD	
Reading fluency (factor score)	0.28	0.85	-0.10	0.77	-1.49	0.39	-1.67	0.49	C = AD > RD = CM
Attention difficulty (max = 110)	3.54	4.68	33.8	11.0	4.74	4.69	39.0	39.0	AD = CM > C = RD
Prior knowledge (max = 3)	1.94	0.38	1.97	0.45	2.03	0.40	1.79	0.43	n.s.
Search query selection (max = 10)	8.00	2.28	7.46	2.15	7.70	1.40	7.75	2.03	n.s.
Information search subskills (max = 3)	2.27	0.31	2.15	0.34	2.02	0.25	1.89	0.37	C = AD > RD = CM
Verbal memory (max = 32)	15.4	2.45	14.8	2.34	13.0	2.16	13.3	2.08	C = AD > RD = CM

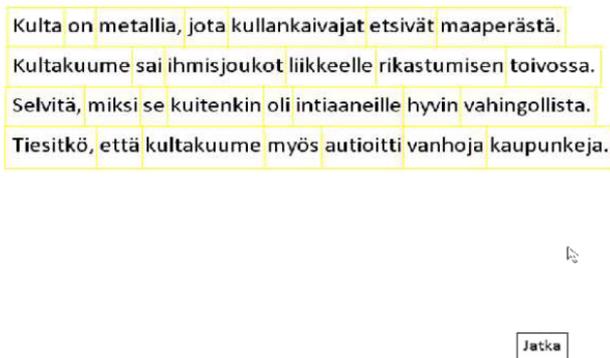


Fig. 1. An example of the task assignment overlaid with automatically generated words-specific area-of-interests (AOIs). These provided the basis for calculation of sentence-specific AOIs.

lengths measured in characters, $t(18) = -0.355$, $p = .741$, and in words, $t(18) = -1.55$, $p = .137$. They also had equal mean word frequency, $t(18) = -0.874$, $p = .394$ based on a Finnish newspaper corpus (Research Institute for the Languages of Finland, 2007). The text was presented in 24-point Calibri font with 1.5 line spacing (1.15), which is sparser than the minimum accuracy limits of the eye tracker's spatial accuracy of 0.5. After the reading, the students continued to the next subtask by clicking the continue (*Jatka*) button.

2.3. Apparatus

The students' eye movements were measured using a table-mounted EyeLink 1000 eye tracker (SR Research). To achieve high spatial accuracy of the eye-movement recordings, each student's head was stabilized using a chinrest and a forehead rest. The stimuli were presented on a Dell Precision T5500 workstation with an Asus VG-236 (1920 × 1080, 120 Hz, 52 × 29 cm) monitor. The participants viewed the stimuli at a distance of 60 cm. Calibration was performed using a 13-point grid with 1 degree of visual angle as the acceptance criterion. The calibration was conducted before the experiment and then repeated between trials when visible head movements were made, when drift was observed on the researcher's screen, or when the calibration-validation error exceeded 0.30 visual degrees.

2.4. Procedure

One research assistant worked with the students in the measurement room, while another assistant controlled the measurement devices in the control room. The students first completed the prior knowledge questionnaire on paper. The information search task then was introduced through a practice task on paper with a research assistant. Next, the table height and forehead rest of eye-tracking system were adjusted, the eye tracker was calibrated, and the students completed one practice task using a mouse. The students then completed the 10 experimental information search tasks, taking one or more short breaks depending on individual needs. The calibration was repeated after each break. The students completed all tasks using a mouse. The experimental session lasted 45 to 90 min, depending on the student.

2.5. Eye-movement data processing

Fixations and saccades were identified according to the criterion of 30 degrees/s using the Data Viewer Program (SR Research Ltd., Canada). To reduce the amount of noise from the fixation detection algorithm and low-level saccadic behaviors, such as rapid corrections of landing position errors (glissades), the exclusion criterion for the fixation duration was < 80 ms (2.6%) and > 1200 ms (0.2%). This is the field standard (see Hawelka, Gagl, & Wimmer, 2010). The four

predefined areas of interest (AOI) corresponded to the four one-line sentences (Fig. 1).

Eye-movement data contain spatial errors (offset), which can be reliably reduced by human correction based on visual inspections (Cohen, 2013). The trained research personnel were unaware of the hypotheses of the study and the qualities of the students. They visually inspected the eye-tracking data to exclude screens with poor-quality eye-tracking data that were beyond repair (2.6% of the screens in the experiment). They also manually repaired systematic offsets in fixation locations on the vertical axis where fixations fall on the wrong side of the AOI boundary. This repair was conducted in 33% of the task assignment screens, which affected 22.1% of fixations. The interrater agreement of whether a trial ought to be corrected between two trained persons for this repair procedure was 91.2%, which was determined using a randomly selected sample of 25 subjects.

A pass-size histogram (i.e., the number of fixations during each visit to sentence AOIs) indicated the presence of two distributions: 1) a large number of skimming passes (Campbell & Maglio, 2001) consisting of one or two fixations; 2) the main distribution of proper reading passes, which averaged on eight fixations. Because skimming passes would produce a large error in the identification of the first and subsequent reading passes of the sentence, all passes with only one or two fixations were excluded before the eye-movement measures were calculated using a custom computer program (Hyönä, Kaakinen, & Penttinen, 2000).¹

2.6. Eye-movement measures

In this study, the progressive fixation duration is the sum of the first-pass fixations located farther on the x-axis than any of the previous fixations. Reinspections are regressive fixations that fall on a previously read part of a sentence during the first-pass reading. Gaze duration is the sum of the durations of progressive and regressive fixations during the first-pass reading. Look-back fixations are fixations that fall on previously read or skipped sentences. The total fixation duration is the sum of all fixation durations on a sentence. In addition to the fixation-duration measures, the probabilities of reinspections and look-backs were calculated.

3. Results

3.1. Descriptive analyses

The group comparison based on the inclusion criteria showed no differences between attention deficit and control groups in cognitive measures except on the attention difficulty scale (Table 1). The reading difficulty and comorbid groups had lower scores on information search and verbal memory. The partial correlations after controlling for reading fluency (Table 2) confirmed that attention difficulty scores were not associated with poorer verbal memory in our sample, but they were associated with slightly poorer information search performance ($r = -0.212$). Higher verbal memory was associated with slightly better information search subskill score ($r = 0.175$).

3.2. Linear mixed models

Separate (generalized) linear mixed-effects models [(G)LMM; Breslow & Clayton, 1993] were fitted for each dependent variable. This approach is the field standard of analysis in the eye-movement research on reading (e.g. Hohenstein, Matuschek, & Kliegl, 2017). Analyses were conducted using an R statistical software engine (version 3.4.2; R Core Team, 2017) in the R Studio environment (version 1.0.136; RStudio

¹ The analysis of skimming probability and duration did not produce statistically significant effects except the reading fluency on the skimming duration.

Table 2
Pearson correlation coefficients between the independent variables.

	1	2	3	4	5
1. Prior knowledge (self-evaluated)	1	0.016		0.009	-0.043
2. Info search subskills	0.062	1		-0.212*	0.175*
3. Reading fluency	0.112	0.421**	1		
4. Attentional difficulties	-0.031	-0.326**	-0.345**	1	-0.032
5. Verbal memory	0.009	0.323**	0.427**	-0.175*	1

Team, 2016). The modeling was conducted using the Analysis of Factorial Experiments (afex) package (Singmann, Bolker, Westfall, & Aust, 2015), which builds on lme4_1.1-14 (Bates et al., 2014) and lmerTest (Kuznetsova, Brockhoff, & Christensen, 2017). The emmeans package (Lenth, 2017) was used to calculate the means and confidence intervals as well as for plotting.

The gamma-distributed fixation-duration variables were log-transformed to obtain normal distributions, which reduced the need to fit complex polynomial terms (Hohenstein et al., 2017). Because of the large variance in the dependent variables, log-transformed values smaller or larger than 2.5 standard deviations from the student mean were excluded (de Leeuw et al., 2016a, 2016b). Durations of a single fixation to a sentence and the low- and high-end tails of each dependent variable, which are specified in the results section for each measure, were also excluded.

Highly skewed predictors are known to be problematic for LMM (Hohenstein et al., 2017). In our preliminary analyses, we found that the highly skewed attention difficulty measure produced spurious interactions. Therefore, this measure was dichotomized on the 75th standard percentile for LMM analyses (17 points; Klenberg et al., 2010). For continuous dependent variables, all three-way interactions between the within-subject factor of relevancy and between-subject covariates (i.e., information search, prior knowledge, reading fluency, attentional difficulty, and verbal memory) were first included in the maximum model. For the GLMMs with dichotomous dependent variables (i.e., the looking probabilities) to converge, the fixed part of the initial model included only two-way interactions with the sentence-type factor.

The models were built according to principles recently suggested in the literature by first fitting a maximal model, reducing it, and then reporting the simplest model that had a fit that was not statistically different from the maximal model (Baayen, Davidson, & Bates, 2008; Barr, 2013; Bates, Kliegl, Vasishth, & Baayen, 2015; Singmann & Kellen, 2017). Type III *sum of squares* tests were applied, which means that lower-order effects were estimated while considering higher-order effects. Sum contrasts were set for the factor predictors by comparing each level to the overall mean of the factor. To obtain convergence of the maximal models, the correlation parameters between random effects were omitted. A random structure was reduced iteratively by first excluding all the highest-level random factors that had variances estimated at zero and refitting the model. Next, the fixed part of the model was reduced iteratively by dropping all the non-significant fixed effects and their corresponding random terms. In the presence of significant interactions, the model fit was compared to the main effects model, in which interactions were omitted. Finally, the correlation parameters of random effects were added, whenever converging. Table 3 shows the statistically significant parameter estimates in proportional or odd-rate values. Table 4 shows the variances in the included random effects of each model. As shown in Figs. 2 and 3, the results are reported in back-transformed original scales; that is, in milliseconds or probabilities.

3.3. Progressive fixation duration

A total of 2870 of 3168 observations (88.6%) were analyzed. Two hundred and thirty-three cases were excluded because the sentence was not fixated at all, 13 were excluded as extreme values (ranging 6 to 9 in

the log-transformed values), and the remaining 48 were excluded because they deviated > 2.5 SD from the subject mean.

The final model contained only the main effect of reading fluency (Table 3) with one standard deviation increase in reading fluency, which reduced the progressive fixation duration by 19.7% (95% confidence interval [CI] = 15.8%–22.7%) when the progressive fixation duration for the average reader was 1700 ms (Fig. 2). The random variability in the progressive fixation duration was relatively small. The largest random effect was the intercept in individuals with 95% CI of 1633–1781 ms (Table 4).

Regarding the first research question, which asked what eye movement measures reflect purposeful reading, the progressive fixation durations clearly did not. The second research question asked which cognitive skills modulate purposeful reading. As expected, progressive fixation durations strongly reflected reading fluency, but not FOKE as one might have expected based on previous studies in adults (Calvo, 2005; Kaakinen et al., 2003). The third research question asked which eye movement measures are sensitive to attentional difficulties. The results showed that the initial progression in reading was similar in students with and without attentional difficulties.

3.4. Reinspection probability

To increase the robustness of the measure, two regressive fixations during the first-pass reading were set as the criteria for reinspection classification, which was the case in 1816 of 3168 observations (57.3%). The final model consisted of the main effects of relevancy and reading fluency. Table 3 present parameter estimates and the results of statistical tests, and Fig. 2 estimated marginal means. Relevancy and reading fluency had the following main effects: regressions were more likely when the students read the relevant sentences (69%) than when they read the irrelevant sentences (47%). One SD increase in reading fluency decreased the regression probability by an odds ratio of 0.73 (95% CI = 0.63–0.84) (see Table 3 and Fig. 2). The large random intercept for the students (0.63) suggests large individual differences in the probability of making regressions in general (95% CI = 34–87%), irrespective of the level of reading fluency or sentence relevancy (Table 4).

These results indicate that the effect of relevancy first manifests in reinspections during the initial reading of relevant sentences. Expectedly, slow decoding ability lead to more reinspections. In contrast to previous studies investigating reading of expository text (e.g. Kaakinen et al., 2015), knowledge and performance measures used the present study (FOKE, information subskill) were not related to reinspection probability. Students with and without attentional difficulties made reinspections with equal probability. There remained substantial individual variability in the probability of making reinspections, which was not associated with reading fluency or sentence relevancy.

3.5. Reinspection duration

A total of 2303 of 3168 observations that included at least a single regression (72.7%) were analyzed; only six values were excluded as outliers. The final model consisted of the statistically significant main effects of relevancy and reading fluency (Table 3). The estimated marginal means (Fig. 2) indicated that one SD increase in reading fluency reduced the reinspection duration by 12% (95% CI = 7.0%–15%) when the reinspection duration of the average reader was 650 ms. The irrelevant sentences were reinspected for 544 ms (95% CI = 459–624 ms) and the relevant sentences for 775 ms (95% CI = 624–962 ms), on average. The random variability in the average reinspection duration was relatively small (95% CI of 613–687 ms) (Table 4). In summary, similar to reinspection probability, the students made longer reinspections to relevant sentences and because of slower decoding ability.

Table 3
Fixed-effects results of the linear mixed-model analyses in a temporally ordered list of eye movement measures.

Model	Effect	OR	Proportional change	CI95%	df	F	χ^2	p
Progressive fix. dur.	Reading fluency		0.81	0.77–0.84	161.8	94.1		< 0.001
	Reinspection, prob.	Relevancy	1.61	1.25–2.04	8		8.69	0.003
Reinspection, dur.	Reading fluency	0.73		0.63–0.84	8		17.6	< 0.001
	Relevancy		1.19	1.08–1.33	9.99	10.1		0.009
Look-back, prob.	Reading fluency		0.88	0.83–0.93	155.9	19.6		< 0.001
	Relevancy	2.27		2.04–2.5	15		19.3	< 0.001
	Attention difficulty	0.78		0.65–0.93	15		8.16	0.004
	Relevancy: attention difficulty	1.22		1.11–1.35	15		11.1	< 0.001
Look-back, dur.	Relevancy: info search level 1 vs. 2	1.26		1.09–1.47	14		9.22	0.01
	Relevancy		1.06	1.01–1.12	12.8	4.98		0.04
	Reading fluency		0.88	0.83–0.93	154.1	18.5		< 0.001

Note. The bold font indicates when each effect first emerged, such as the effect of reading fluency appeared during progressive fixations, whereas the effect of relevancy first appeared in reinspection probability. Abbreviations: OR = odds ratio, prop. = proportional, fix. = fixation, dur. = durations.

3.6. Look-back probability

In 1041 of 3168 sentence reads (33%), there was a look-back containing at least three fixations, which was our distribution-based criteria for a proper reading pass whereas one or two fixation passes were interpreted as skims. The final model consisted of the main effects of relevancy, attention deficit, the information subskills score, the interactions between relevancy and attention deficit, and the interactions between the relevancy and the information search score. The model produced a convergence warning, but all optimizers produced the same results, in which case the warning can be taken as a false positive (Bates et al., 2014). All but the main effect of the information score were statistically significant predictors in the model (Table 3). Fig. 3 illustrates the nature of the interactions. The effect of relevancy was larger in students with intact vs. deficient attentional functioning. While both groups looked back at the irrelevant sentence with equal low probability (11%–12%, 95% CIs: 7%–17%) the students with intact attentional functioning looked back at the relevant sentence with much higher probability (54%, 95% CI = 45%–63%) than the students with attentional difficulties did (30%, 95% CI = 22%–40%). The interaction between relevancy and the information search subskill, indicated that trials with lowest vs. highest scores were associated with the greater likelihood of looking-back at a relevant sentence. The probability of look-backs to relevant sentences was 31% (95% CI = 23%–41%) for trials with low information subskill score and 45% and 50% (95% CIs = 36%–59%) for medium and high information subskill score, respectively. The large random intercept for the students (Table 4) suggests huge unexplained variability in the probability of performing look-backs in general (95%, CI = 4–65%).

In summary, look-back probability reflected higher cognitive processes than decoding aspects of reading. As predicted on the basis of RESOLV model, making more look-backs to the relevant sentence was associated with better scores in the informational task. Crucially, the attention-deficit group made less look-backs to relevant sentences, suggesting highly selective influence of attention deficit on comprehension monitoring processes. However, there remained huge

Table 4
Variances of the included random intercept (id, item) and the random slopes (factor $_{item/id}$) in the linear mixed-model analyses.

Model	id	Relev. _{id}	IS _{id}	item	Relev. _{item}	IS _{item}	Residual
Progressive fix. duration	0.07	0.003		0.006	0.002		0.07
Reinspection, probability	0.63	0.08		0.15	0.14		
Reinspection, duration	0.08	0.02		0.04	0.03		0.66
Look-back, probability*	0.84	0.19	0.08	0.06	0.11	0.0008	
Look-back, duration	0.07	0.01		0.01	0.002		0.27

Note. The values are given in logarithmic scale for continuous duration measures and log-odds for dichotomous probability measures. To concretize the random effects sizes, the confidence intervals for the individual intercept (id) are given in the text in original scale.

Abbreviations: *uncorrelated random effects structure. Relev. = Relevancy, IS = Information search subskill score, fix. = fixation.

individual in the probability of making look-backs.

3.7. Look-back duration

In 1016 of 3168 observations (32%), there was a look-back containing at least three fixations (and therefore not considered a skimming pass), which was not an extreme value (29) outside a log-transformed value of six to nine. Again, the final model consisted of the statistically significant main effects of relevancy and reading fluency (Table 3). The estimated marginal means (Fig. 3) indicated that an increase of one standard deviation in reading fluency reduced the look-back duration by 12% (95% CI = 7%–17%) when the duration for the average reader was 1693 ms. The irrelevant sentences were viewed for 1594 ms (95% CI = 1407–1806 ms), and the relevant sentences were viewed for 1798 ms (95% CI = 1606–2014 ms) on average. The random variability of individuals in average look-back duration was modest (95%, CI = 1603–1785 ms (Table 4).

In addition to being more frequent, look-backs were also longer in relevant sentences. Slower reading speed predicted longer durations in looking-back at both sentence types. Attention deficit had no influence on look-back duration.

3.8. Bivariate latent change score modeling

The preceding results suggest that first- and second-pass viewing reflected partially different cognitive processes. However, in these analyses, the possible interdependency between first- and second-pass viewing was not considered. For example, during the first-pass viewing, the students might have searched only the relevant sentence and return to read it properly later, in which case short first-pass viewing times would predict long look-back times and vice versa. Bivariate latent change score modeling (Kievit et al., 2017) was used to study how sentence relevancy effects in gaze duration and look-back duration measures depend on each other. This modeling takes the two main cognitive predictors of reading fluency and attention difficulties into account.

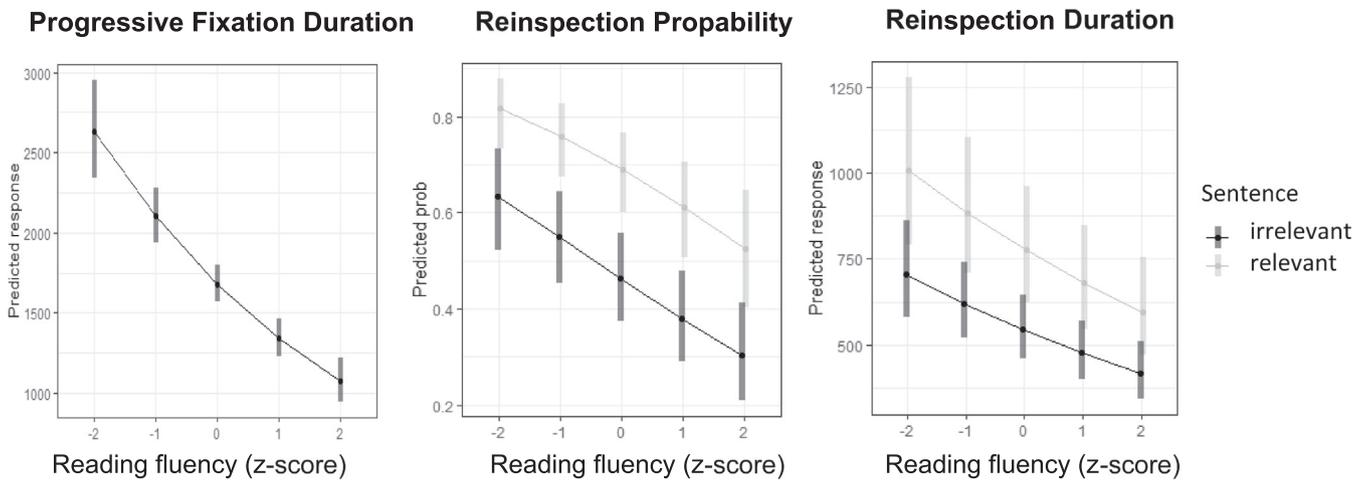


Fig. 2. Predicted estimated means and 95% confidence intervals for statistically significant effects on first-pass eye-movement measures. The scale for the duration measures is in milliseconds.

The model was constructed using Mplus 8.0 (Muthén & Muthén, 1998-2017). A full information maximum likelihood method with robust standard error estimates and scale corrected chi-square test value against non-normality (MLR estimator in Mplus) was used. The model was modified by adding covariances and regression paths with the help of modification indices. The model fit was evaluated using a chi-square test value and the standardized root mean square error (SRMR). In a well-fitting model, the chi-square test value is non-significant and the SRMR is lower than 0.08. Finally, bias-corrected bootstrapped 95% confidence intervals for parameter estimates were calculated.

The analysis was begun by defining the difference factors (i.e., the latent change score models). The eye-movement variable values were transformed to a logarithmic scale, and the variables were standardized. The regression coefficient and factor loadings were fixed to one (marked as * in Fig. 4). The regression coefficients derived from the irrelevant sentences to the difference factors of the relevant sentences were freely estimated. Two independent variables—reading fluency and attention difficulty score—were added to the model. After that, the two paths of reading fluency were added based on large modification indices. The model fit increased clearly when one path from attentional difficulties was added with two residual covariances, which resulted in a good model fit: $\chi^2(5) = 8.21, p = .145, SRMR = 0.037$.

In the model, better reading fluency was associated with shorter gaze duration for irrelevant sentences and a smaller difference between relevant and irrelevant sentences in gaze duration. A higher attention

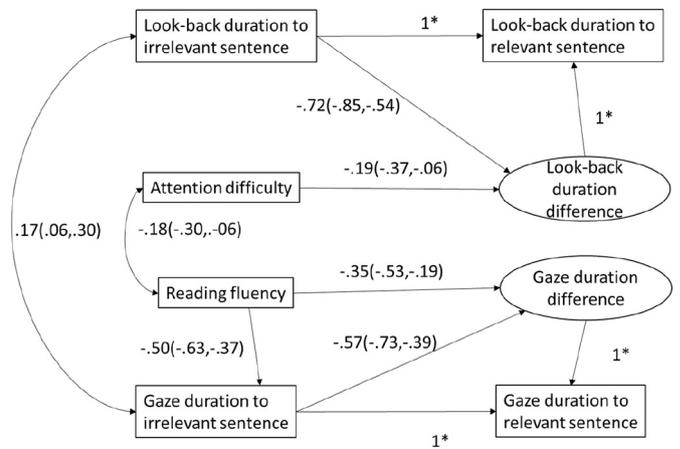


Fig. 4. Path diagram of the bivariate latent change score model with parameter estimates and 95% bias-corrected bootstrap confidence intervals in parentheses.

difficulty score was associated with a smaller difference in look-back duration for relevant and irrelevant sentences. These results confirmed the results of separate analyses of eye movement measures by showing that the second-pass fixation duration was relatively independent from the first-pass fixation duration and that attention difficulty was specifically associated with shorter look-back durations at relevant

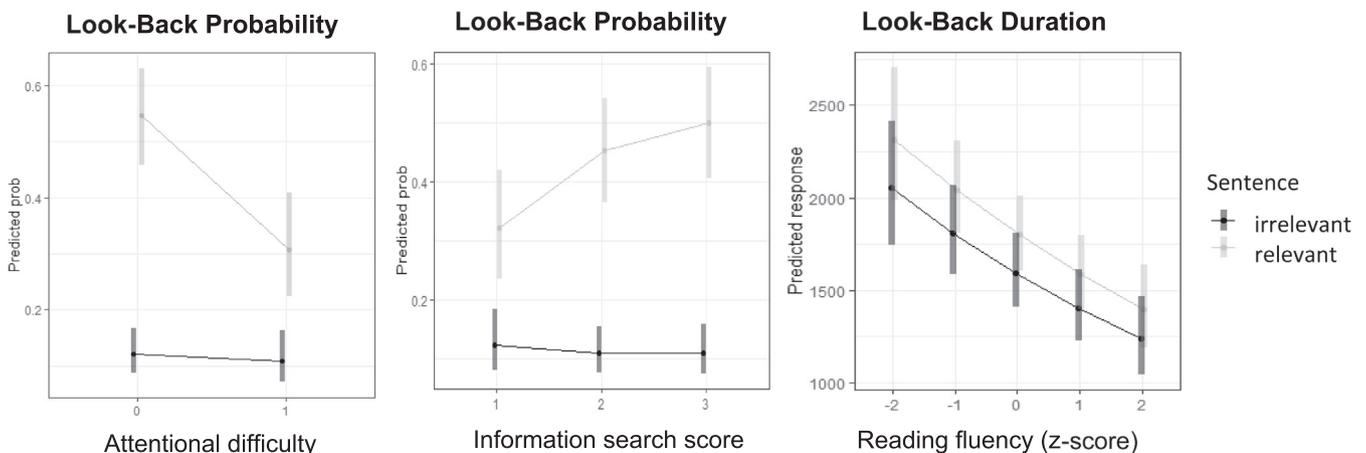


Fig. 3. Predicted estimated means and 95% confidence intervals for statistically significant effects on second-pass eye-movement measures. The scale for the duration measures is in milliseconds.

sentences.

4. Discussion

This study explored the associations between sentence-level eye-movement measures and selected cognitive skills, including reading fluency, information search skill, prior knowledge, verbal memory, and attentional difficulty in sixth-grade students. The results of the structural equation modeling showed high independence of the first- and second-pass viewing, which also reflected different cognitive abilities. These results validate the general assumption that while first-pass eye movement measures reflect predominantly decoding aspects of reading, look-backs reflect more strategic and conscious reading processes, such as metacognitive comprehension monitoring (Cerdán et al., 2011; Hyönä et al., 2002; Hyönä & Nurminen, 2006). We will first review the findings in the temporal order they appeared, followed by a theoretical discussion.

Reading fluency predicted all the sentence-level eye-movement measures except the probability of making look-backs at a previously read sentence. This stable and substantial influence across reading processes is understandable because higher reading fluency decreases the number of fixations and their duration (Hawelka et al., 2010), including reinspections, as shown in many previous studies (for the developmental trend, see Kaakinen et al., 2015). Reinspections in slower readers presumably stem from word decoding difficulties, poorer vocabulary knowledge (de Leeuw et al., 2016a, 2016b), or difficulties integrating word meaning into the sentence context (Schulz et al., 2008).

Purposeful reading was assessed by the extent to which readers paid more attention to the task-relevant than the irrelevant sentences. This effect emerged first in the probability of making reinspections during the first-pass reading of the sentence, and it remained significant in all later measures. The relevancy effect on reinspections can be understood as a reader's attempt to ascertain his or her comprehension of the relevant or important part of the text (Hyönä & Nurminen, 2006; Kaakinen et al., 2015). However, in line with previous studies (Cerdán et al., 2011; Schoot et al., 2008), this early level of comprehension monitoring was not related to performance in the informational task.

Look-backs at relevant parts of a text are believed to reflect a reader's conscious strategy to build a cohesive mental model of the text (Hyönä & Nurminen, 2006). Our study provided further evidence that the decision to look-back is not governed by reading fluency processes even in children (Hyönä & Nurminen, 2006). Most of the look-backs were directed at the relevant sentence and were of longer duration than look-backs at irrelevant sentences, which has been previously found in children in the fourth grade onwards (Kaakinen et al., 2015).

Previous studies have shown that rereading an important part of the text is associated with better reading comprehension performance (Cerdán et al., 2011; Hyönä et al., 2002; Hyönä & Nurminen, 2006). Also in the present study, returning to the relevant sentence was beneficial for completing the informational task; that is, it was associated with a higher task score. The present pattern of results suggests that while reinspections reflect merely detection of important information, look-backs reflect the strategic understanding of its relevancy to later behavior. However, the present and previous studies (Calvo, 2005; Hyönä et al., 2002), indicate high individual variability and reasons for making look-backs. Low task demands in our study most likely enabled many readers to construct a good enough task model without repeating the relevant sentence.

Attentional difficulty was associated with making less look-backs at relevant sentences. The implication is that attentional difficulty does not affect an individual's initial reading of a text, but it does disturb higher-level comprehension monitoring and regulation processes (Berthiaume et al., 2010), which in turn has negative consequences for reading comprehension performance. This finding is the most important in the present study demonstrating the potential for an eye-tracking

methodology in the study of attention control in attention deficiency.

4.1. Implications for the theoretical understanding of purposeful reading

The present results add to our knowledge of purposeful reading (Britt et al., 2017; Rouet et al., 2017) by showing that construction of the task model typically involves additional processing stages from linear reading. The construction begins by reinspections in relevant sentences, but it is specifically achieved by strategic look-backs to the relevant sentences. In accordance with the task model guidance hypothesis of the RESOLV model (Britt et al., 2017; Rouet et al., 2017), look-backs at relevant sentences were associated with better performance in the informational task.

Instead, feelings-of-knowing evaluations or verbal memory abilities were not crucial constraints for constructing the task model despite of previous such findings in adults (Burton & Daneman, 2007; Calvo, 2005; Kaakinen et al., 2003). Presumably, the generally low task requirements of reading short task assignments did not sufficiently stress these processes to produce significant findings. The findings suggest that the verbal memory capacity and feelings-of-knowing evaluations may not be the key constraints in the construction of a routine task model, at least for straightforward search prompts. Instead, a more crucial factor seems to be reader's schematic understanding of the task requirements; that is, a small investment in a look-back to rehearse or check the task objective has positive consequences in subsequent stages of the reading activity. Overall, the present findings are in line with the RESOLV model's prediction that contextual factors involving task requirements and reader's schematic expertise modulate which task model construction processes are stressed.

4.2. Independent influences of reading fluency and attention difficulty on reading processes

Comprehension difficulties in dyslexia are thought to result from attentional working memory resources being reserved to word decoding (Miller et al., 2013). Accordingly, we observed slightly poorer information searching performance and verbal memory ability in students with reading difficulties. However, slow reading fluency was not associated with any disturbances in purposeful reading behavior. These results rule out the possibility that decoding difficulties take attentional resources away from the semantic processing of a text, at least in the reading of short and simple connected texts.

Comprehension difficulties in attention-deficit individuals have been associated with impaired working memory and metacognitive comprehension monitoring abilities. Miller et al. (2013) further suggested that limited working memory resources may be spent on sustaining attention at the cost of higher-level comprehension processes. To specify this attentional deficiency further, we predicted: 1) impaired metacognitive comprehension monitoring should result in less attention paid to the relevant sentence (Hyönä & Nurminen, 2006); 2) impaired working memory span should increase the attention paid to task-relevant sentences (Burton & Daneman, 2007). After controlling for reading fluency, the partial correlations indicated only weak associations between attention difficulty scores, verbal memory span, and information subskill score. For eye movements, the attention deficit was associated with an intact relevancy effect during the first-pass reading; however, the students were less likely to make look-backs to the relevant sentences. Attention deficit has also been associated with the tendency to value speed over accuracy (Mulder et al., 2010), but this explanation would also predict faster first-pass reading times with a lower number of reinspections, which was not observed. Therefore, we conclude that the present findings suggest impairment in the metacognitive comprehension monitoring processes, which was previously established (Alvarado et al., 2011; Berthiaume et al., 2010; Pezzica et al., 2018). At the schematic level, this impairment may consist of not acknowledging the crucial importance of constructing a task model

properly.

Finally, our sample included 24 students who had comorbid reading and attentional difficulties but performed equally with the reading difficulty group in other behavioral measures. Note that previous studies have shown that comorbid groups have a distinct cognitive profile, such as high processing speeds (Willcutt et al., 2010) and more severe working memory deficits (Bental & Tirosh, 2007) compared with groups with only reading or attention deficits. Because no interaction of low reading fluency and attentional difficulty was detected, we conclude that the influence of these difficulties on sentence-level reading behavior is simply additive, with the restriction that our sample did not consist comorbidity associated with additional deficiency in verbal memory.

4.3. Practical implications

The present findings suggest that not all children learn to focus on the relevant information in task assignments on their own and could therefore benefit from targeted reading strategy instruction. Such instruction might involve reflection on what part of the task assignment is crucial to understand and remember in order to complete the task. In addition, students should be guided in monitoring their own comprehension and memory representation of the task assignment so that they learn to notice when they are ready to proceed to the actual task. Interventions that teach students to detect critical information and concentrate on reading or rereading the critical parts of a text may be particularly useful for students with attentional difficulties. However, further studies are required to verify the effectiveness of such interventions.

4.4. Strengths and limitations of the study

The strengths of this study are the use of a large sample size representing a wide range of reading and attention abilities, several control variables, and advanced statistical analyses with converging findings, which enabled firm conclusions to be drawn from the results.

However, the generalizability of the findings may be limited to the reading of short texts that explicitly prompt subjects to remember a crucial piece of information. Therefore, additional studies are needed to understand how attention, reading, and other cognitive skills affect semantically guided eye movements during reading with respect to target words embedded in single sentences and to reading long or difficult texts that require complex look-back behavior to build a coherent representation of the text.

The limitations of this study concern the use of the self-report scale to measure prior knowledge, which is known to be less reliable than objective measures (Dochy, Segers, & Buehl, 1999). However, the self-report scale was in accordance with the feeling-of-knowing evaluation proposed by the purposeful reading theory (Rouet et al., 2017). That said, asking students to evaluate their knowing after reading of each search prompt, would have been even more accurate way of assessing their feeling-of-knowing. Another limitation of the study concerns the homogenous structure of the search prompts including recurrent procedural wording ('Find out', 'Figure out') at the beginning of task objective sentence, which may have exaggerated the re-reading of these sentences.

In conclusion, the findings of the present study stress the importance for students to understand reading tasks and construct task-relevant strategies. Such strategies should be systematically taught in schools, with special attention paid to students with learning difficulties.

Declaration of competing interest

None.

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Appendix A. Task assignment texts in their presentation order and with their English translations

Practice		
	Tiesitkö, että koralliriuttoja kutsutaan merten sademetsiksi. Selvitä, millaisia uhkia riutoilla on ilmastonmuutoksen lisäksi. Ilmastonmuutos koettelee koralliriuttoja maailmanlaajuisesti. Suuren koralliriutan rakentuminen vie lähes miljoona vuotta.	Did you know that coral reefs are called rain forests of the sea? Find out what threats reefs face in addition to climate change. Climate change threatens coral reefs globally. The development of a large coral reef takes almost a million years.
1	Kautta historian kulta on ollut arvostetuimpia maametalleja. Suomen maaperässä kultaa esiintyy lähinnä Lapin alueella. Ota selvää, mistä maailman suurin kultahippu on löydetty. Löytäjää on hädän tuskin jaksanut nostaa niin painavaa hippua.	Throughout history, gold has been one of the most prestigious soil metals. In Finnish soil, gold is found mainly in Lapland. Find out from where the world's largest gold nugget has been found. The discoverer has hardly been able to lift it up.
2	Kulta on metallia, jota kullankaivajat etsivät maaperästä. Kultakuume sai ihmisjoukot liikkeelle rikastumisen toivossa. Selvitä, miksi se kuitenkin oli intiaaneille hyvin vahingollista. Tiesitkö, että kultakuume myös autioitti vanhoja kaupunkeja.	Gold is an earth element that miners seek from soil. Many people were involved in the Gold Rush, hoping to get rich. Find out why the Gold Rush was very harmful for American Indians. However, many people did not get rich during the Gold Rush.
3	Lääketieteessä hoidon tehokkuus osoitetaan tutkimuksiin. Selvitä seuraavaksi, mitä lumelääkkeellä oikein tarkoitetaan. Lääketutkimuksiin tarvitaan monia vapaaehtoisia ihmisiä. Arvaat varmaan, että tutkimus vaatii hurjasti töitä tutkijoilta.	In medicine, treatment efficiency is being proven by research. Figure out next what placebo means. One needs a lot of volunteers to run drug research. You probably know that it requires a lot of work by researchers.
4	Toisinaan urheilijat ovat sortuneet kiellettyihin keinoihin. Dopingissa lääkkeitä käytetään suorituskyvyn parantamiseen. Selvitä, missä lajissa tehdään eniten dopingtestejä Suomessa. Urheilijoiden tulee olla tarkkana, mitä lääkkeitä he käyttävät.	Sometimes athletes succumb to using forbidden methods. In doping, drugs are used to improve performance. Figure out in which sport the most doping tests are done in Finland. Sportsmen should be cautious about which drug they use.
5	Erakkoluontoinen panda on kasvissyöjä, joka liikkuu hitaasti. Ota seuraavaksi selvää, miksi pandakarhut ovat uhanalaisia. Poiketen tavallisista karhuista, isopandat eivät nuku talviunta. Talvellakin pandat viettävät aikaa ravintoa etsien ja leväten.	Retired pandas are herbivores who move slowly. Find out next why panda bears are endangered. Unlike ordinary bears, big pandas do not hibernate. Even in winter, pandas spend time searching food and resting.
6	Pandat ovat ainoita karhuja, joilla on mustavalkoinen turkki. Ota selvää, montako pandaa luonnossa elää tänä päivänä. Nämä nallekarhut elävät luonnossa noin 14–20-vuotiaiksi. Pandat muuten asuvat bambumetsissä Kiinan vuoristoissa.	Pandas are the only bears that have black and white fur. Find out how many pandas are living in the wild today. These teddy bears reach the age of 14 to 20 years in the wild. Pandas live in bamboo forests in mountain ranges in China.
7	Rokotteiden avulla estetään tarttuvien tautien leviäminen. Niiden ansiosta tarttuvien tautien leviäminen pysyy kurissa.	Vaccines are used to prevent the spread of contagious diseases. They keep the spread of contagious diseases under control.

	Selvitä, kuinka monta prosenttia pikkulapsista rokotetaan. Jos rokotuksia ei annettaisi, niin taudit leviäisivät vapaammin.	Find out what percentage of small children are being vaccinated. If vaccinations were not given, diseases would spread freely.
8	Joidenkin vanhempien mielestä rokotukset ovat vaarallisia. Selvitä, miksi heidän mielestään lapsia ei pitäisi rokotuttaa. Tutkijat pyrkivät vähentämään rokotteiden haittavaikutuksia.	Some parents think vaccinations dangerous. Find out why they think children should not be vaccinated. Researchers try to reduce the harmful side effects of vaccinations.
9	Silti myös he kiistelevät rokotusten hyödyistä ja haitoista. Ryhävalas eroaa muista valaista ison pyrstönsä perusteella. Isosta pyrstöstä on melkoisesti hyötyä pitkällä uintimatkoilla. Selvitä, miksi ne uivat lähes puoli maapallonmittaa vuosittain. Muutamia on joskus harhautunut myös Helsingin lähistölle.	Yet they also debate about the pros and cons of vaccinations. Humpback whales differ from other whales by their big tail. A big tail is highly useful during long swimming travels. Figure out why they swim almost half of the globe annually. A few of them have sometimes lost their way near Helsinki.
10	Tiesitkö, että ryhävalaita voidaan tavata kaikkialla valtamerillä. Selvitä, kuinka pitkän muuttomatkan ne tekevät vuosittain. Ryhävalaat poikkeavat selvästi muista valaista ulkonäöltään. Ne ovat suuria ja niillä on kokoonsa nähden isot kylkievät.	Did you know that humpback whales live in every ocean? Find out how long a migration travel they swim annually. Humpback whales differ clearly from other whales by their appearance. They are big and they have relatively big side fins.

References

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