



# Task-oriented reading efficiency: interplay of general cognitive ability, task demands, strategies and reading fluency

Jarkko Hautala<sup>1,6</sup> · Ladislao Salmerón<sup>2</sup> · Asko Tolvanen<sup>3</sup> · Otto Loberg<sup>4</sup> ·  
Paavo Leppänen<sup>5,6</sup>

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## Abstract

The associations among readers' cognitive skills (general cognitive ability, reading skills, and attentional functioning), task demands (easy versus difficult questions), and process measures (total fixation time on relevant and irrelevant paragraphs) was investigated to explain task-oriented reading accuracy and efficiency (number of scores in a given time unit). Structural equation modeling was applied to a large dataset collected with sixth-grade students, which included samples of dysfluent readers and those with attention difficulties. The results are in line with previous findings regarding the dominant role of general cognitive ability in the accuracy of task-oriented reading. However, efficiency in task-oriented reading was mostly explained by the shorter viewing times of both paragraph types (i.e., relevant and irrelevant), which were modestly explained by general cognitive ability and reading fluency. These findings suggest that high efficiency in task orientation is obtained by relying on a selective reading strategy when reading both irrelevant and relevant paragraphs. The selective reading strategy seems to be specifically learned, and this potentially applies to most students, even those with low cognitive abilities.

**Keywords** Information literacy · Task-oriented reading · Eye movements · Reading efficiency · Learning disabilities

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✉ Jarkko Hautala  
jarkko.hautala@nmi.fi

<sup>1</sup> Niilo Mäki Institute, Asemakatu 4, FI-40014 Jyväskylä, Finland

<sup>2</sup> Department of Developmental and Educational Psychology, University of Valencia, Valencia, Spain

<sup>3</sup> Faculty of Education and Psychology, University of Jyväskylä, Jyväskylä, Finland

<sup>4</sup> Department of Psychology, Bournemouth University, Bournemouth, UK

<sup>5</sup> Department of Psychology, University of Jyväskylä, Jyväskylä, Finland

<sup>6</sup> Centre for Interdisciplinary Brain Research, University of Jyväskylä, Jyväskylä, Finland

## Introduction

Finding relevant information swiftly is a basic task-oriented reading skill. Most research has focused on explaining accuracy in task-oriented reading with adult participants (e.g., OECD, 2019; Rouet, 2006; Rouet et al., 2017; Snow, 2002; Vidal-Abarca et al., 2011). However, there is an emerging interest in understanding efficient reading strategies (Soederberg Miller, 2009; León et al., 2019) and in how students' various *cognitive skills* (e.g., reading fluency) define their processes and outcomes in purposeful reading (for reviews, see Anmarkrud et al., 2018; Ben-Yehudah et al., 2018).

In the current study, we analyzed how adolescents find an answer to an informational task on a well-structured page. Our focus was identifying the generic processes and cognitive foundations that underlie accuracy (i.e., scores) and efficiency (i.e., task score divided by time spent on task) in task-oriented reading skills.

## Task-oriented reading

*Task-oriented reading* is the ability to read one or more texts to achieve a specific goal (Vidal-Abarca et al., 2010). Essential to task-oriented reading is *text relevance*, which pertains to the sections of a text that include information useful for completing the reading task. This differs from *text importance*, which is related to which parts of a text are necessary to fully understand that text (McCrudden & Schraw, 2007).

The Task-based Relevance Assessment and Content Extraction (TRACE) model attempts to specify the process of task-oriented reading (Rouet, 2006). This model identifies a sequence of crucial steps, starting with understanding of the task demands (Cerdán et al., 2019; Tawfik et al., 2020), then constructing a *task model*, followed by gathering information from the text to create a *document model*. Readers must continue to search for and focus on relevant information, discard irrelevant information, and determine when sufficient information has been gathered to solve the task. This procedure is believed to be conceived of as a series of complex cycles in which the previous steps determine how subsequent steps are implemented (Rouet, 2003).

In accordance with the TRACE model, people are found to put effort into the proper construction of the task model. They spend more time reading difficult questions than easy questions (Martínez et al., 2009) and questions that demand a global understanding of a text rather than a local one (McCrudden et al., 2010; Rouet et al., 2003; Cerdán et al., 2009).

Concerning the construction of the document model, people generally spend longer reading relevant sections than irrelevant sections (McCrudden & Schraw, 2007). Relevant parts of a text are also returned to more often or for a longer period of time (Yeari et al., 2015; see also Hautala et al., 2019; Kaakinen et al., 2015), which presumably indicates the prolonged semantic processing of that content. A larger relevancy effect is associated with better accuracy in task-oriented reading (e.g., higher scores on comprehension questions; Hautala et al., 2019; Salmerón

et al., 2017). More general questions may induce more time spent reading the document (Rouet, 2003), yet null effects have also been reported (Cerdán et al., 2009; Rouet et al., 2001; Salmerón et al., 2017). However, these studies have probably differed in the difficulty of locating specific answers from complex hypertexts or multiple documents used in the studies. Eye-movement studies suggest that a specific goal induces readers to be more selective in their reading than when reading for general comprehension, spending more time viewing relevant content and less time viewing irrelevant content in the former case (León et al., 2019; McCrudden & Schraw, 2007). Overall, when the task is more difficult (e.g., *why-* vs. *what-questions*, general vs. specific, or integrate vs. locate), readers seem to spend more time detecting, locating and/or reading the relevant parts of the text (Rouet, 2003; Rouet et al., 2001).

Focusing on relevant information may also contribute to *task efficiency*, which is a neglected aspect of reading comprehension and task-oriented reading research (Soederberg Miller, 2009). The concept of efficiency can be incorporated into current theoretical views (Stine-Morrow et al., 2006; Britt et al., 2017). Accordingly, readers allocate attention to a text in a way that enables them to construct a representation of the passage that is “good enough” to achieve their current reading goals and relative to their abilities and other situational factors. However, to our knowledge, Soederberg Miller (2009) is the only study of reading efficiency in the context of a text recall task (i.e., the amount of information recalled from each paragraph). Soederberg Miller found that efficiency was correlated with accuracy at the 0.6–0.7 level and with reading time at the 0.4–0.6 level, providing evidence that efficiency is a sufficiently separate aspect from accuracy and speed. This is already the case for a task that requires only a rudimentary level of reading comprehension.

One potential way to attain high efficiency in task-oriented reading is to rely on a selective reading strategy (León et al., 2019), i.e., by trying to read only relevant parts of text. Selective reading strategies can be supported by informative *headings*, which have been shown to facilitate performance in search tasks (Lorch et al., 2011). In principle, in search tasks with informative headings, readers may *strategically* select to read only the relevant paragraph. However, selectivity may also manifest more generically, for example, by continuously adapting reading *depth* according to text relevance (Yeari et al., 2015). Given that even relevant paragraphs also contain less relevant parts, efficiency may be explained by shorter reading times for both relevant and irrelevant paragraphs.

## Foundation for task-oriented reading

According to Britt et al. (2017), readers’ cognitive resources (or skills) provide a foundation for individuals’ purposeful reading comprehension abilities. Cognitive skills are intercorrelated to the extent that the concept of *general cognitive ability* is justified (Jensen, 1998). High general cognitive ability indicates that a student can master diverse types of tasks given through verbal instructions and can therefore be assumed to exhibit high control over his or her reading behaviors (Rouet, 2003, 2006). General cognitive ability may support comprehension, e.g., via an increased

ability to conduct more fine-grained inferences between multiple text elements (Moehring et al., 2016).

General cognitive ability is thought to be captured by the first-order factor of performance in cognitive assessments, operationally defined as the g-factor (Jensen, 1998), on which reading and literacy skills (Alloway & Gregory, 2013; Rindermann, 2007; Wolf et al., 2012) and executive and working memory functions (Packwood et al., 2011) are strongly loaded. The g-factor is influenced by genetic and environmental factors, among which the child's parental language proficiency and educational level are the most influential (Hart & Risley, 1995). The g-factor is also a relevant concept for understanding learning disabilities, which are typically accompanied by lower levels of performance in several cognitive skills (Laasonen et al., 2020).

In a previous study, 83% of adults' accuracy in a multiple-choice task-oriented reading task was explained using fluid and crystallized intelligence measures (Moehring et al., 2016). In a different study, when controlling for reading fluency and comprehension, a nonverbal reasoning measure, the Raven Standard Progressive Matrices (RSPM), explained only 14% of adolescents' scores in a complex task-oriented reading task requiring the writing of summaries (Kanniainen et al., 2019).

More research with a diverse set of predictors is needed to unravel the extent to which task-oriented reading relies on general cognitive ability on the one hand and on residual variance in *specific* skills on the other. These specific skills may also be more malleable than general cognitive ability and thus deserve the most instructional effort in education (Kempe et al., 2011; Stuebing et al., 2009).

The strongest candidate for a specific skill that can explain task-oriented reading is one's reading *comprehension skill*, defined as the ability to identify the main information in a text and to use inferences and prior knowledge to gain a complete understanding of it (Cataldo & Oakhill, 2000; Salmerón et al., 2015, 2017, 2018; Sung et al., 2015; Vidal-Abarca et al., 2010). Evidence indicates that high comprehenders perform more accurately than low comprehenders in task-oriented reading tasks (Cataldo & Oakhill, 2000; Salmerón et al., 2015, 2017, 2018; Sung et al., 2015; Vidal-Abarca et al., 2010). High comprehenders are more selective in their reading, they spend relatively less time reading irrelevant paragraphs to answer more challenging questions, with no difference observed in easier questions (Salmerón et al., 2017). They also spend extra time reading important topic sentences (Sung et al., 2015).

Poor attention skills have also been associated with difficulties in task-oriented reading (Ben-Yehudah & Brann, 2019; Hautala et al., 2019; Stern & Shalev, 2013). Utilizing eye-tracking methodology, Hautala et al. (2019) found that in reading task assignments, poor reading fluency was associated with overall longer first-pass reading times for sentences, whereas attention problems were associated with a lower probability of making selective look-backs specifically at relevant sentences (Hautala et al., 2019). The results were interpreted to indicate that attentional problems impair comprehension monitoring. Additionally, poor reading fluency may limit the attention resources available for comprehension processes (Kanniainen et al., 2019). Poor readers have consistently been found to rely more on external cues, such as text highlighting, than typical readers (Bar-Zvi Shaked et al., 2020).

Research has produced somewhat mixed results concerning the importance of prior knowledge in task-oriented reading (Coiro, 2011; Cromley & Azevedo, 2009; Moehring et al., 2016; (Rouet, 2003; Soederberg Miller, 2009). Efficiency in a reading recall task has been explained rather poorly by age and working memory (Soederberg Miller, 2009), suggesting that efficiency relies mostly on a reader's learned competence.

Overall, research suggests that task demands, reading strategies, and cognitive skills contribute to task-oriented reading, yet they are seldom studied together. From a theoretical perspective, the lack of such studies limits our understanding of the generic processes underlying task-oriented reading. From a pedagogical perspective, this situation limits our ability to provide appropriate support to students with task-oriented reading difficulties.

### The current study

In this study, we aimed to explicate the relationships between the g-factor and selective reading strategy in explaining accuracy and efficiency in task-oriented reading. Students whose reading and attention skills ranged broadly (Anmarkrud et al., 2018; Ben-Yehudah et al., 2018) were asked to locate and verbally report the answers to easy and difficult questions that contained irrelevant and relevant paragraphs presented on a computer screen while their eye movements were recorded. Note that in the framework of the TRACE model, the present investigation is limited to the subprocess of document model construction.

While most previous research has been concerned with testing conditional differences in group averages, our study used structural equation modeling (SEM) to model the direct and mediated associations of cognitive skills to a *reading process* (conceptualized as time spent viewing irrelevant and relevant paragraphs) and to accuracy and efficiency outcomes. The students were expected to be selective in their reading and thus spend more time reading relevant paragraphs than irrelevant ones. However, this selective reading strategy may manifest both in strategically selecting which paragraph to read or as a more generic process of spending less time reading regardless of a paragraph's relevancy. Regarding different performance aspects, high accuracy may be obtained with a thorough reading of both paragraphs, whereas high efficiency may require the use of a selective reading strategy. These effects of reading strategy should appear even when statistically controlling for reading fluency, which is expected to strongly explain fixation times.

Previous studies have not studied diverse sets of cognitive skills in conjunction with each other; therefore, it is not clear whether task-oriented reading relies mostly on general cognitive ability or, for instance, on attention or reading skills. Another novel aspect of the present study is to analyze both accuracy and efficiency (Soederberg Miller, 2009) in task-oriented reading. Because high accuracy may be obtained regardless of the reading strategy used, cognitive skills may directly explain accuracy, whereas viewing times may mediate the effect of cognitive skills on efficiency.

On the other hand, task difficulty may induce multidimensionality in both process and outcome measures. Multidimensionality means that while most variability is

shared between easy and difficult questions, there may also be a significant amount of unique variability in each task type, which may have a specific association with other measures. Obtaining high accuracy in answering difficult questions may be more dependent on one's general cognitive ability or reading comprehension than is the case when answering easier questions.

## Method

### Participants

This study's participants were involved in the neurocognitive substudy of the eSeek research project focusing on internet reading skills in a large inclusive sample of 426 sixth-grade students (Kiili et al., 2018). To more closely study the possible unique influences of learning difficulties (e.g., reading dysfluency, attention difficulties, and their comorbidity), representative students, along with many randomly selected control students, from the classroom study were screened. The 164 sixth-grade participants (age  $M = 12$  years 4.2 months,  $SD = 3.7$  months; 98 boys and 66 girls) were thus invited to take individual cognitive assessments and eye-tracking measurements in the laboratory setting as a subsample. The specific inclusion and exclusion criteria for each measure are given in the 7 section below, and the number of participants in each recruitment group is given in Table 1. The eye-tracking measurement failed with three students, whose data were thus excluded from the analysis. In accordance with the Declaration of Helsinki, we obtained written consent from all students and their guardians before the study. Ethical approval for this study was received from the ethics board of the University of Jyväskylä.

### Measures

The maximum scores, observed means, and standard deviations are given in Table 1.

*Attention difficulties* were assessed using a 55-item Attex attention-deficit questionnaire (internal reliability of Cronbach's  $\alpha = 0.95$ ) completed by the teachers (Klenberg et al., 2010) as a part of the classroom study. All students who scored higher than the 75th standardized percentile (17 points) were invited to participate in the individual assessment study. Higher scores indicated greater attention problems. Depending on their performance in the reading fluency screening tasks, these students were assigned either an attention difficulty or a comorbid group status (see Table 1).

*Reading fluency* was assessed using three tasks: a word identification task (Lindeman, 1998), pseudoword text reading (Eklund et al., 2015), and a word chain segmentation test (Holopainen et al., 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 the performance of these three tests by principal axis factoring with promax rotation (SPSS). All students below the 15th percentile in reading fluency were invited to participate in the study. Depending on

their scores on the Attex task, these participants were assigned either a difficult or a comorbid group status (see Table 1).

The *RSPM* (Raven, 1998) is a nonverbal reasoning task. A shortened version containing 30 items was used; these items comprised every second item from the larger test (Wytek et al., 1984) and Cronbach's  $\alpha = 0.81$  for these items (Kanerva et al., 2019). To exclude the possibility that very low general cognitive ability would affect the results, students performing lower than the 7th percentile (approximately 16 points) in the classroom sample were not invited to participate in this study.

The *visual attention* task (NEPSY-II: Korkman et al., 2008) requires a participant to scan an A3 sheet and mark specified visual targets among several similar distractors (e.g., face drawings). The score equals the number of correct responses minus the number of incorrect responses given within three minutes.

The *symbol search* task (WISC-IV: Wechsler, 2003) measures several functions of visuospatial attention. The participant must search for target symbols from a search group with a two-minute time limit. The score equals correct minus incorrect responses.

The *animal sorting* task (NEPSY-II:  $\alpha = 0.54$ ) measures concept formation, the ability to apply concepts, and set-shifting. The task requires participants to sort cards into two groups of four cards each using various self-initiated sorting criteria. The score equals the number of correct responses.

The *block design* task (WISC-IV:  $\alpha = 0.91$ ) measures a child's ability to analyze and synthesize abstract visual stimuli. The task requires a participant to recreate a displayed model by using red-and-white blocks within a 45-second time limit. The score equals the number of correct responses.

The *memory for designs, immediate and delayed* task (NEPSY-II: test-retest = 0.87) assesses visuospatial memory. The participant must remember a series of non-figural abstract shapes and their positions on a grid. In immediate or delayed recall conditions, the participant is asked to select target shapes from a set of cards and position them on an empty grid. The score equals the sum of points derived from fully correct (two points) or partially correct responses (one point).

The *word list interference* task (NEPSY-II:  $\alpha = 0.76$ ) assesses verbal working memory, repetition, and word recall following interference. The participant is presented with two lists of words and then asked to repeat each list. Then, the participant is asked to recall each list in the order it was presented. The scoring takes into account partially correct responses.

The *digit span* task (WISC-IV:  $\alpha = 0.80$ ) assesses short-term and working memory by requiring participants to repeat a list of digits spoken by an instructor in the same or reverse order that it was presented in. The score equals the sum of correct responses.

*Reading comprehension* (Lindeman, 1998) was assessed with one subtask from a standardized reading test (Cronbach's  $\alpha = 0.64$ ; Revelle's  $\alpha = 0.86$ ) administered as a group test in the classroom study. Participants read an expository text (instructions for consumers) and responded to 12 multiple-choice questions (four options) that represented the following categories: (1) detail/fact (one question); (2) cause-effect/structure (one question); (3) conclusion/interpretation (four questions); (4) concept/phrase (three questions); and (5) main idea/purpose (three questions). The two-page



text was available to participants when responding to the questions. The maximum score was 12 points.

The *rapid naming* task (RAN: Denckla & Rudel, 1976) assesses the automatization of the sequential naming of familiar items. The child names a matrix of randomly ordered items aloud from a set of five items. Both letter and object subtasks were administered.

The *vocabulary* task (WISC-IV, = 0.96) measures a child's word knowledge and verbal concept formation by requiring the child to name the pictures in a stimulus book. For the verbal items, the child must give definitions for the words the examiner reads aloud. The score equals the sum of the points for each item (0, 1, 2).

## Information search experiment

First, *self-evaluated prior knowledge* on the topics covered in the information search experiment was assessed using a self-rating scale (e.g., "How much do you know about the threats to coral reefs?") administered on a sheet of paper before the experiment. 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 a fair amount (9.4% of responses); and (5) I know a lot about the subject (1.3% of responses). Because of the small number of responses indicating high prior knowledge, categories 3–5 were combined to achieve an evenly distributed three-category scale. Reliability across the 10 tasks was  $\alpha = 0.68$ .

Then, the students, without a time limit, completed 10 tasks that simulated searching for information on the internet. Each task consisted of a sequence of subtasks: (1) reading a four-line text specifying the task assignment; (2) selecting a search query from among five alternatives; (3) selecting a search result from among four alternatives; (4) reading a static webpage where the answer was located at either the beginning or at the end of a relevantly titled paragraph, which was one of the two paragraphs presented on the screen (see Fig. 1); and (5) reporting the answer verbally to a research assistant after leaving the webpage. Short instruction prompts 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 repeated on an instruction screen immediately before entering the webpage. To provide some thematic continuation in the lengthy experiment, two adjacent tasks always shared a common theme. Only eye movements during the fourth subtask (i.e., the webpage screen; see Fig. 1) are investigated in this present paper.

Five of the tasks involved 'easy' questions that required finding a single fact, whereas five of the tasks involved 'difficult' questions; correct answers consisted of two aspects placed successively in the text within the relevant paragraph. The placement of easy and difficult questions in the experiment, the position of the relevant paragraph (upper or lower), and the answer location within the relevant paragraph varied in a fixed pseudorandom order, thus being equivalent for each participant. To enable the effective use of task-oriented reading strategies, the paragraph's relevancy for the information search



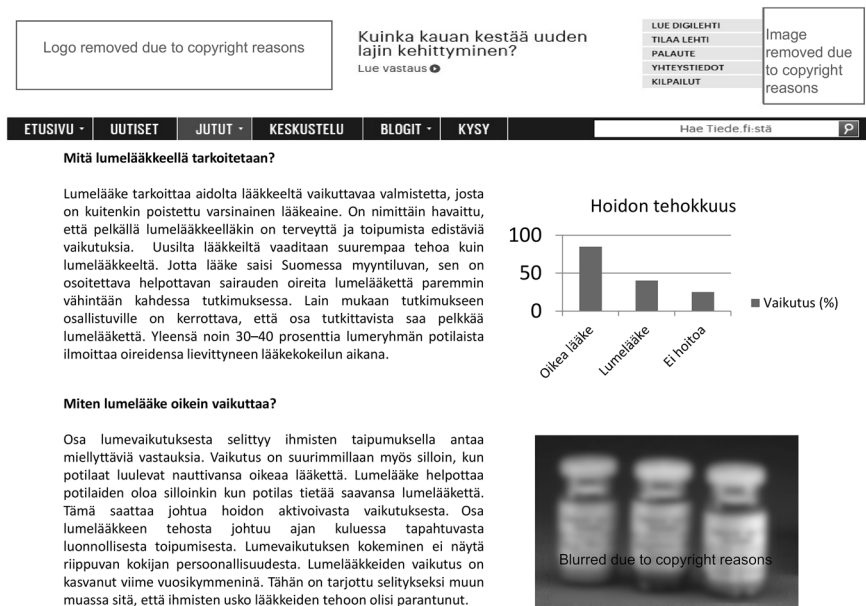


Fig. 1 Example of a stimulus screen

task was cued by the semantic content of the paragraph titles. Lengthy paragraphs were used to induce a high benefit of the selective reading strategy on task efficiency.

The *accuracy* of the students' responses was determined by audio recording their verbal answers, which were transcribed and scored by trained research assistants according to predefined criteria for accurate responses. The easy questions were scored as 0 or 1, and the difficult questions were scored as 0, 1, or 2, corresponding to the number of correct aspects of the student's answer. For example, for the difficult question 'What is a placebo?', the aspects were (a) a product resembling genuine medicine, (b) out of which the effective substance has been removed. The interrater reliability of the scores of the verbal responses was high ( $\alpha=0.95$ ) in a random sample of 20 participants (i.e., 200 responses). *Time-on-task values*—the time (sec) a student viewed the screen—were derived from the eye tracker's result files. *Information search efficiency* was calculated by dividing the score in a trial by the corresponding time-on-task values.

The assignment for this task stated, "Find out what the placebo means in medicine." The relevant paragraph was hinted at by the overall title, "What is a placebo?", whereas the title of the irrelevant lower paragraph was "How does a placebo exert its influence?"

## Apparatus

The students' eye movements were measured using a table-mounted *EyeLink 1000* eye tracker (SR Research). To achieve the high spatial accuracy of the eye-movement recordings, each student's head was stabilized using a chin rest and forehead

**Table 1** Descriptive results for the recruited participant groups

Measure	Recruitment groups								Multiple comparisons (Bonferroni)	
	C (n = 89)		AD (n = 28)		RD (n = 23)		CM (n = 24)			
	M	SD	M	SD	M	SD	M	SD		
<i>Screening measures</i>										
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 difficulties (Max = 110)	3.49	4.64	33.8	11.0	4.74	4.69	39.0	39.0	AD, CM > C, RD	
Raven matrices (Max = 30)	23.2	3.1	22.0	3.6	21.7	3.2	20.4	2.9	C>CM	
<i>Outcome measures</i>										
<i>Accuracy</i>										
Easy questions (Max = 1)	0.91	0.12	0.90	0.16	0.87	0.15	0.78	0.19	C, AD > CM	
Difficult questions (Max = 2)	1.28	0.42	1.12	0.46	0.90	0.46	0.81	0.42	C > RD, CM	
<i>Efficiency (score/s)</i>										
Easy questions	0.043	0.019	0.043	0.022	0.032	0.024	0.032	0.023	n.s.	
Difficult questions	0.035	0.016	0.030	0.010	0.021	0.010	0.020	0.008	C > RD, CM; AD>CM	
<i>Process measures</i>										
<i>Fix. time, relevant paragraph(s)</i>										
Easy questions	29	10	28	9	42	17	38	15	C, AD<RD, CM	
Difficult questions	44	25	41	12	54	16	50	20	n.s.	
<i>Fix. time, irrelevant paragraph(s)</i>										
Easy questions	15	11	20	14	31	24	28	19	C<RD, CM; AD<RD	
Difficult questions	15	11	20	14	32	23	28	19	C<RD, CM; AD<RD	
<i>Answer area(s)</i>										
Easy questions	5.8	2.9	5.3	1.8	7.2	2.8	6.5	3.4	n.s.	
Difficult questions	17.4	12.9	15.1	7.0	18.3	6.1	17.6	9.0	n.s.	
<i>Cognitive measures</i>										
Feeling-of-knowledge (Max = 3)	1.94	0.38	1.97	0.45	2.03	0.40	1.79	0.43	n.s.	
Reading comprehension (Max = 12)	7.8	2.4	6.1	2.4	5.7	1.8	4.7	2.2	C>AD, RD, CM	

**Table 1** (continued)

Recruitment groups									
	44	6	41	6	38	6	39	6	
Vocabulary (Max = 66)	23.5	5.4	22.5	4.0	26.6	4.8	28.1	6.1	C, AD>RD, CM
RAN letters (s)	41.3	6.7	43.3	6.6	47.1	8.1	50.3	7.7	C, AD<CM; AD<RD
RAN objects (s)	45.7	9.1	41.0	9.2	42.1	11.9	41.1	10.9	C, AD<CM; C<RD
Block design (Max = 68)	15.4	2.47	14.8	2.34	13.0	2.16	13.3	2.08	n.s.
Digit span (Max = 32)	128	18	120	19	124	24	116	21	C > CM, RD; AD>RD
Memory for the design (Max = 150)	6.1	1.6	5.6	1.6	5.3	1.6	5.1	2.2	n.s.
Animal sorting (Max = 11)	22.5	7.4	19	5.1	19.7	5.1	15.4	5.9	C>CM
Visual attention (Max = 38)	37.5	5.0	35.2	5.5	35.5	5.0	34.1	4.2	C>CM
Word list interference (Max = 60)	31.0	5.7	29.5	5.5	27.7	6.4	26.2	4.2	C>CM
Symbol search (Max = 60)									

Abbreviations: C = Control; AD = attention difficulties; RD = reading difficulties; CM = comorbid reading and attention difficulties; Fix = fixation

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 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.

## 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 *self-evaluated prior knowledge* questionnaire on paper. The information search task was then introduced with a practice task on paper with a research assistant. Next, the table height and the forehead rest of the eye-tracking system were adjusted. The eye tracker was calibrated, and the students completed one practice task using a computer mouse. During each task sequence, the students were required to make only a couple of mouse-controlled selections with no time limit and low requirements for spatial accuracy. The students then completed the experiment, taking one or fewer breaks depending on their needs. The calibration was repeated after each break. Each experimental session lasted 45–90 min, depending on the student. The students were instructed to complete the tasks as accurately and quickly as possible.

## Eye-movement data processing

Fixations and saccades were identified according to the criterion of 30 degrees per second using the *DataViewer* program (SR Research). We analyzed only the total fixation time for the irrelevant and relevant paragraphs, including their titles, and for the answer area.

Eye-movement data contain spatial errors (offset), which can be reliably reduced by manual correction based on visual inspections (Cohen, 2013). The trained research personnel were unaware of the hypotheses of this study and the students' abilities. They visually inspected the eye-tracking data to exclude screens with poor-quality eye-tracking data that could not be remedied (i.e., 2.6% of the screens in the experiment). The researchers also manually repaired systematic offsets in fixation locations on the vertical axis where fixations fell on the wrong side of the area-of-interest (AOI) boundary. This repair was conducted for 56% of the webpage viewing screens, which affected 17.4% of the fixations.

The high rate of corrected screens was due to multiple elements on the screen, the viewing of which consisted of highly complex scan paths requiring frequent minor corrections of fixation positions falling on the wrong side of the AOI boundary. The researchers documented their repairs on an action level (e.g., shifting all fixations on a screen upward). The interrater agreement on the repair action (or lack of action) was 87.2%.

## Statistical analyses

Descriptive analyses were carried out with analysis of variance (ANOVA). Due to the large between-subject variance, fixation times were analyzed both in absolute values (seconds) and as proportions to overall screen viewing time. However, in the SEM modeling, only absolute values were applied to enable reading skill measures to explain the between-subject variance in fixation times.

The goal of SEM modeling is to explain the relationships between measured and latent variables and the relationships among latent variables. The model building began by examining whether there was evidence for two latent factors corresponding to the easy and difficult questions. To this end, the easy and difficult factor models were tested against the one-factor model separately for accuracy, efficiency, and fixation times for relevant (FixRel) and irrelevant (FixIrrel) paragraphs. Likewise, the second-order factor (Fix) captured the highly correlated first-order factor of FixIrrel and FixRel.

To prevent multicollinearity due to high correlations between cognitive measures (except *self-evaluated prior knowledge*; see Appendix), a common latent factor (i.e., the g-factor) for cognitive measures was specified. Then, modification indices indicated whether the residual of a certain cognitive measure was associated with outcome or process measures over the g-factor, in which case, the specific factor for the residual was set. This allowed the residuals to directly predict outcome and process measures. The entire model was then specified by regressing the identified factors to the outcome measures (accuracy or efficiency) and the second-order factor of fixation (Fix) on the g-factor.

All estimations were made using the *Mplus* statistical package, version 8.3. Missing values were assumed to be randomly missing. To address possible deviations from normal distributions, full information maximum likelihood methods with robust standard error and chi-square test values were used in the estimation. In exceptional cases, the weighted least square mean and variance adjusted (WLSMV) method was used when testing the two-factor model against the one-factor model for the accuracy measure because this measure had only two (easy questions) or three categories (difficult questions). The model fit was evaluated with the chi-square test value, root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker–Lewis index (TLI), and standardized root mean square residual (SRMR). The cutoff values for a well-fitted model were a nonsignificant chi-square test value,  $RMSEA < 0.06$ , CFI and TLI close to 0.95, and  $SRMR < 0.08$  (Hu & Bentler, 1999; Muthén, 1998–2004).

## Results

### Descriptive analyses

Table 1 presents the descriptive statistics for the participants according to the identified study groups. Overall, in terms of outcome and process measures, control participants (C) and those with attention difficulties (AD) showed somewhat higher

accuracy and efficiency in the information searching tasks and shorter fixation times on both irrelevant and relevant paragraphs than those with reading difficulties (RD) and those with comorbid reading and attention difficulties (CM). However, not all comparisons were significant after Bonferroni corrections. The same tendency was present in the cognitive measures, in which CM seemed to consistently show the lowest scores. Notably, all groups spent longer viewing relevant paragraphs than irrelevant paragraphs (in particular, the answer area in difficult questions), thus showing evidence for task-oriented reading.<sup>1</sup>

## Factor analysis

To test whether the easy and difficult questions tap into different skills and processes, a two-factor solution was compared against a one-factor solution for all four outcome and process measures—that is, accuracy, efficiency, and fixation time on relevant and irrelevant paragraphs.

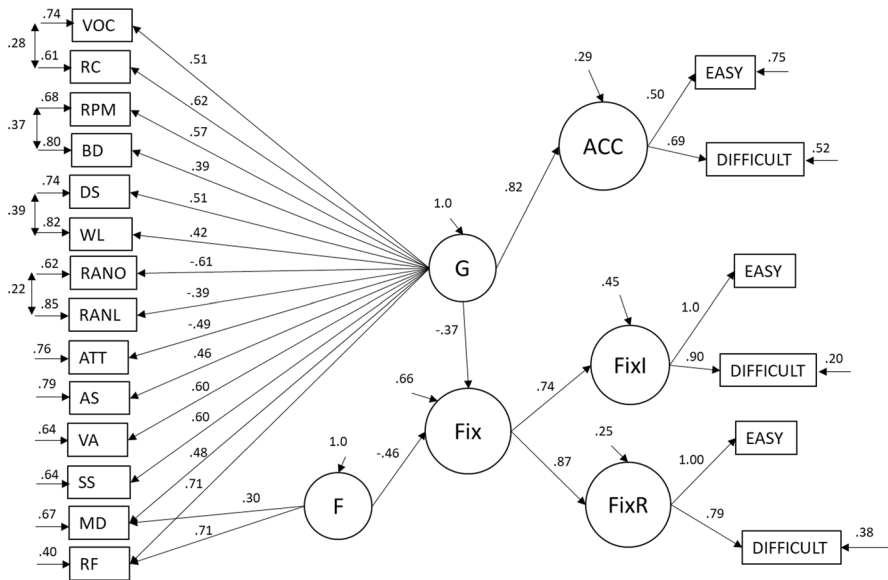
For the accuracy measure, the two-factor model did not fit the data better than the one-factor model,  $\chi^2(1) = 1.04$ ,  $p = 0.307$ . In the two-factor model, the factors were highly correlated,  $r = .95$ . For the efficiency measure, the two-factor model fit the data better than the one-factor model,  $\chi^2(1) = 6.92$ ,  $p = .009$ , and the two factors showed high correlation,  $r = .78$ .

For fixation time on the relevant paragraph, the two-factor model fit the data better than the one-factor model,  $\chi^2(1) = 81.61$ ,  $p < .001$ , and the factors showed high correlation,  $r = .81$ . For fixation time on the irrelevant paragraph, the two-factor model did not fit the data better than the one-factor model,  $\chi^2(1) = 3.33$ ,  $p = .068$ , but again, the factors of the two-factor model showed high correlation,  $r = .97$ . Despite only partial support being obtained for easy and difficult factors, two sums corresponding to easy and difficult questions were calculated for the four measures due to the desire to reduce the model complexity. This reduction is needed to fulfill the requirement of sample size relative to model complexity (Wolf et al., 2013).

## Accuracy model

All of the cognitive measures loaded on the g-factor, with the standardized beta coefficient ( $\beta'$ ) ranging from 0.39 for RAN letters to 0.71 for reading fluency (see Fig. 2). In the final model (see Fig. 2), a higher score on the g-factor predicted a directly and strongly higher score on the accuracy factor ( $\beta' = 0.82$ ,  $R^2 = 0.67$ ). Higher scores on the g-factor also predicted lower scores on the fixation factor ( $\beta' = -0.37$ ), i.e., shorter paragraph viewing times, on which fixation times on both irrelevant ( $\beta' = 0.74$ ) and relevant ( $\beta' = 0.87$ ) paragraphs were strongly loaded.

<sup>1</sup> There was a significant task number and task difficulty interaction, indicating that over the course of the experiment, the students became more efficient in answering the *what* questions (from 0.011 to 0.022 scores per second) but not the *why* questions (from 0.016 to 0.015 scores per second),  $F(4, 572) = 19.74$ ,  $p < .001$ ,  $\eta_p^2 = 0.121$ .

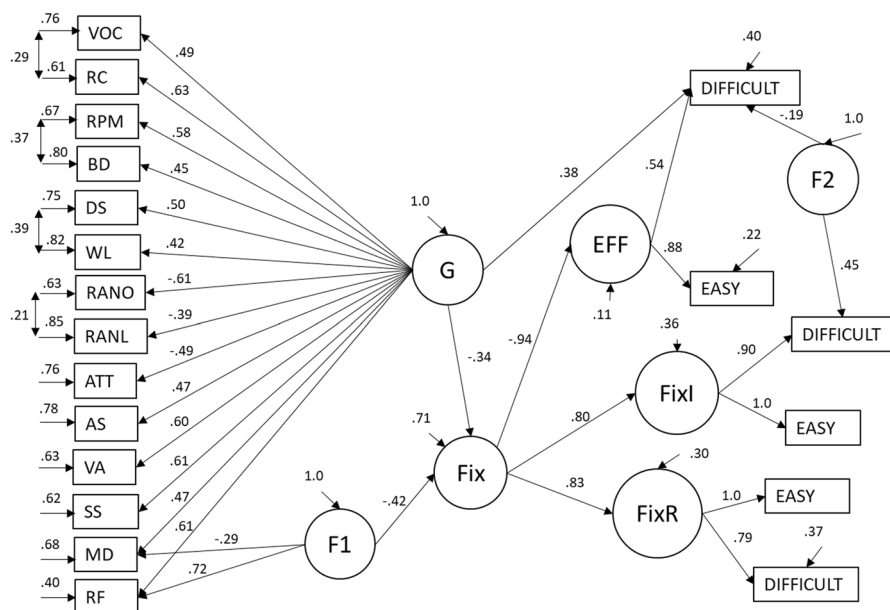


**Fig. 2** Structural equation model for accuracy in task-oriented reading. The standardized beta values are shown in this figure. The nonconnecting arrows are residuals. Abbreviations: VOC = vocabulary; RC = reading comprehension; RPM = Raven, BD = block design; DS = digit span; WL = word list interference; RANO = RAN objects; RANL = RAN letters; ATT = attention difficulties; AS = animal sorting; VA = visual attention; SS = symbol search; MD = memory for designs; RF = reading fluency; G = g-factor; F = specific factor; Fix = fixation time; FixI = fixation time on the irrelevant paragraph; FixR = fixation time on the relevant paragraph; ACC = accuracy in task-oriented reading

As expected, poor reading fluency predicted longer fixation times via the specific factor F ( $\beta' = -0.32$ ), while the association from memory to design task to fixation via the specific factor F is not readily interpretable. Neither of the indirect paths (derived by multiplying the coefficients paths) of theoretical interest, that is, neither the effect of the g-factor via fixation to accuracy nor that from the reading fluency factor via fixation to accuracy, was significant. Together, these results indicate that accuracy in task-oriented reading is mostly determined by general cognitive ability, not by viewing times, which were, in turn, somewhat shorter for students with high cognitive ability and reading fluency.

The model building progressed as follows: accuracy and fixation factors were regressed on the g-factor. Reading fluency and memory for the design task to fixation loaded on an additional specific factor, F, which did not correlate with the g-factor. This made it possible to add the specific association needed in the model, independent from the g-factor; that is, fixation was regressed on this specific factor. The model needed four residual covariances between block design and the Raven matrices, between word list interference and digit span, between vocabulary and reading comprehension, and between RAN objects and RAN letters. Note that despite these pairs coherently representing underlying cognitive constructs according to modification indices, they were not associated with process and outcome measures over and above the g-factor.





**Fig. 3** Structural equation model for efficiency of task-oriented reading. Abbreviations in addition to those listed in Fig. 2: F1 = specific factor; F2 = specific factor 2; EFF = efficiency

The two small, negative residual variances were fixed to zero in the final accepted model, which fit well enough to the data:  $\chi^2(160) = 249.72$ ;  $<0.001$ ; RMSEA = 0.058, CFI = 0.92; TLI = 0.91; SRMR = 0.067. Even though the chi-square test value was statistically significant and the CFI and TLI were lower than required for a well-fitted model, the modification indices were small, showing that no extra parameters were needed for the model. This is also shown by the small RMSEA ( $<0.06$ ) and SRMR ( $<0.08$ ) values. In the final model shown in Fig. 2, the standardized parameter coefficients are all statistically significant.

## Efficiency model

In the final model (see Fig. 3), the observed variable of efficiency in easy questions ( $\beta' = 0.88$ ,  $R^2 = 0.77$ ) loaded more strongly than the observed variable of efficiency in difficult questions ( $\beta' = 0.54$ ,  $R^2 = 0.29$ ) on the first-order factor of efficiency. First-order factors fixation times on both irrelevant ( $\beta' = 0.80$ ,  $R^2 = 0.64$ ) and relevant ( $\beta' = 0.83$ ,  $R^2 = 0.67$ ) paragraphs loaded strongly on the second-order factor of fixation time.

Lower scores on the fixation factor then very strongly predicted higher scores on the efficiency factor ( $\beta' = -0.94$ ,  $R^2 = 0.89$ ). Notably, the g-factor directly, albeit weakly, predicted the efficiency of the difficult questions by  $\beta' = 0.38$  ( $R^2 = 0.14$ ). As expected, poor reading fluency predicted longer fixation times ( $\beta' = -0.42$ ). The negligible specific association from memory to design to fixation was not readily

interpretable. There were two significant indirect effects from the g-factor via fixation to efficiency ( $\beta' = 0.32$ ,  $p < .001$ ,  $R^2 = 0.10$ ) and from the reading fluency factor (F1) via fixation to efficiency ( $\beta' = 0.39$ ,  $p < .001$ ,  $R^2 = 0.15$ ). Additionally, longer residual fixation time on irrelevant paragraphs predicted slightly poorer efficiency in difficult questions ( $\beta' = -0.19$ ,  $R^2 = 0.04$ ). The results indicate that efficiency in task-oriented reading is mostly determined by viewing time, which also largely mediates the influence of reading fluency and general cognitive ability on efficiency. However, efficiency in difficult questions is also directly explained by higher cognitive ability.

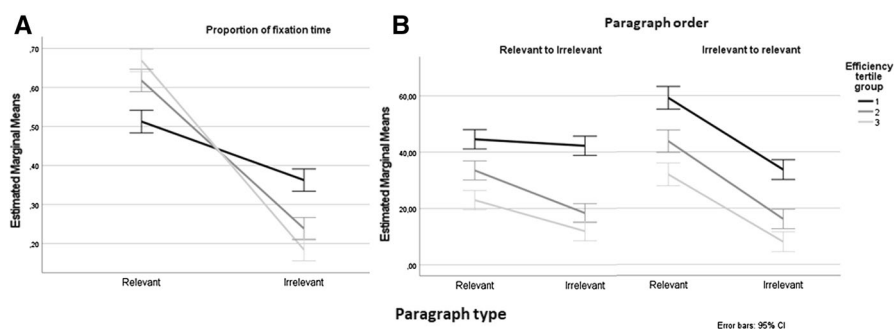
The model building progressed as follows: Efficiency was regressed on fixation, and fixation was regressed on the g-factor. Similar to the accuracy model, reading fluency and memory for designs loaded on an additional specific factor (F1) that did not correlate with the g-factor. Fixation was regressed on this specific factor. Efficiency in the difficult question was regressed on the g-factor. A specific factor (F2) capturing the association between fixation times on irrelevant paragraphs and efficiency in the difficult question was added. The model needed six residual covariances between reading comprehension and vocabulary, between block design and the Raven matrices, between word list interference and digit span, and between RAN objects and RAN letters.

The small, negative residual variances were fixed to zero in the final accepted model, which fits well to the data:  $\chi^2(160) = 231.07$ ;  $p < 0.001$ ; RMSEA = 0.052; CFI = 0.94; TLI = 0.93; SRMR = 0.068. Even though the chi-square test value was statistically significant and the TLI was slightly lower than required for a well-fitted model, the modification indices were small, showing that no extra parameters were needed for the model. This is also shown by the high CFI ( $> 0.90$ ), small RMSEA ( $< 0.08$ ), and SRMR ( $< 0.08$ ) values. In the final model shown in Fig. 3, the standardized parameter coefficients are all statistically significant.

## Supplementary analyses

We further studied whether efficient readers are more selective in their reading, that is, whether they show a larger relevancy effect and perhaps respond differently to paragraph order. To this end, a full-factorial repeated-measures ANOVA was run for absolute fixation times proportional to screen viewing time. This analysis included two-level factors of question type (easy and difficult), paragraph order (relevant to irrelevant and irrelevant to relevant), and paragraph type (relevant and irrelevant) and included efficiency tertile group as a between-subject factor. The critical interaction of the relevancy and efficiency groups was not significant in absolute values,  $F(2, 155) = 3.016$ ,  $p = .052$ ,  $\eta_p^2 = 0.037$ , but it was highly significant in proportional values of screen viewing time,  $F(2, 155) = 31.983$ ,  $p < .001$ ,  $\eta_p^2 = 0.292$ . Panel (a) in Fig. 4 shows how efficient task-oriented readers allocated much more of their viewing time to relevant paragraphs than to irrelevant paragraphs.

Paragraph order interacted strongly with relevance in both absolute values,  $F(2, 155) = 175.3$ ,  $p < .001$ ,  $\eta_p^2 = 0.531$ , and proportional values,  $F(2, 155) = 132.2$ ,  $p < .001$ ,  $\eta_p^2 = 0.460$ . Panel (b) in Fig. 4 shows how fixation times for relevant



**Fig. 4** Results of the supplementary analyses of fixation times

paragraphs were inflated when preceded by an irrelevant paragraph. Additionally, the three-level interaction of efficiency group  $\times$  order  $\times$  relevancy was significant in absolute values,  $F(2, 155) = 8.094$ ,  $p < .001$ ,  $\eta_p^2 = 0.095$ , but not in proportional values,  $F(2, 155) = 2.911$ ,  $p = .057$ ,  $\eta_p^2 = 0.036$ , resulting from a tendency of inefficient readers to view an irrelevant paragraph for a particularly long time when it was presented after a relevant paragraph.

Panel (a) shows the fixation times proportional to the screen viewing time, and Panel (b) shows the fixation times in relation to paragraph order.

## Discussion

To unravel the generic factors underlying task-oriented reading skill, associations between readers' cognitive skills and viewing times of relevant and irrelevant paragraphs on task-oriented reading outcomes (accuracy and efficiency) were analyzed by SEM on a large sample of sixth-grade students, among whom reading ( $n = 23$ ) and attention difficulties ( $n = 28$ ) or their comorbidity ( $n = 24$ ) were overrepresented relative to the control group ( $n = 89$ ).

Overall, the students performed better on the easy questions than the difficult questions and spent considerably more time viewing relevant paragraphs than irrelevant paragraphs, which was mostly due to specifically viewing the answers. Proportional to the students' overall screen viewing time, unlike less efficient readers, more efficient readers allocated more attention to relevant information and less attention to irrelevant information.

These results are in accordance with the previous understanding that having a specific task leads to selective reading, and this tends to be the case more for skilled task-oriented readers than for unskilled readers (Cerdán & Vidal-Abarca, 2008; Cromley & Azevedo, 2009; Hautala et al., 2018; Kaakinen et al., 2015; León et al., 2019; Salmerón et al., 2017; Yeari et al., 2015).

## Reading strategies

First, whether efficiency in task-oriented reading is obtained due to a strategic decision to read only the relevant paragraphs, as cued by an informative heading, was studied. The fixation times on irrelevant and relevant paragraphs formed a strong viewing time factor, indicating that students who spent little time viewing irrelevant paragraphs read relevant paragraphs faster.<sup>2</sup> Supplementary analyses further specified that students spent the same amount of time reading the irrelevant paragraph irrespective of whether it came located first or second on the screen, likely to ensure it did not contain relevant information.

These results suggest a continuous regulation of one's reading *depth* according to local variations in text relevancy (Yeari et al., 2015; Hautala et al., 2018; Kaakinen et al., 2015; Rouet, 2006; Salmerón et al., 2015) rather than making a clear-cut strategic decision about which paragraph to read. These findings are highly compatible with the TRACE model (Rouet, 2006) and its extensions (RESOLV: Rouet et al., 2017) in the sense that reading is continuously controlled by goal-oriented schemas and representations.

Second, it was hypothesized that while high accuracy could be obtained with a thorough reading of both paragraphs, obtaining high efficiency would require relying on a selective reading strategy. In accordance with this prediction, viewing times only slightly explained the accuracy (8%), indicating that the correct answer could also be extracted through either a swift or a prolonged reading of the texts. Instead, efficiency was explained almost solely by the viewing time factor (88%). These results provide further support for efficiency being an important and separate construct to accuracy in basic informational tasks (Soederberg Miller, 2009). Our results also indicate that reading strategies are more central to obtaining high efficiency than to being accurate.

How might the continuous regulation of reading depth operate, leading to high differences in efficiency? Typically, people read through a text first to obtain an overview and then return to the most relevant part of the text (Hautala et al., 2018; Kaakinen et al., 2015; León et al., 2019; Yeari et al., 2015). This strategy is typically associated with comprehension benefits (Cerdán et al., 2009; Rouet et al., 2003). It does not require inhibiting oneself from a response (Wilson et al., 2003) to read the whole text presented. However, people seem to differ considerably in how they construct a text representation (see, e.g., Salmerón et al., 2017). Efficient readers seem to rely more on preexisting schemas of task and text structure (Cataldo & Oakhill, 2000)—that is, on the assumption that only a small piece of information is relevant (also within a relevant paragraph) and that it is unlikely to be scattered across both paragraphs. Instead, less efficient readers may lack such schemas and, consequently, may be more attuned to exploring the text extensively. Our supplementary analyses of fixation times provide some support for this stance. Having already read the

<sup>2</sup> At the extreme, for the easy questions, the most efficient one-third of the students viewed irrelevant paragraphs for 8 s on average and relevant paragraphs for 23 s.

answer in the preceding relevant paragraph did not help the inefficient readers spend less time on reading the subsequent irrelevant paragraph.

Finally, the highly structured task with several repetitions induced some learning: The students doubled their efficiency in answering the easy fact-finding tasks, but such development was not observed with more difficult tasks. During the course of the experiment, students probably started to learn and anticipate that the answer would always be found in a single location. When the task was easy, this learning was directly reflected in efficiency. Instead, efficiency in difficult tasks seems to be more dependent on the students' ability to semantically encode the information. We will return to this point in the next section when discussing the role of the g-factor in task-oriented reading.

### Cognitive skills and task-oriented reading

Third, the association between cognitive skills and task-oriented reading was studied. General cognitive ability was expected to explain accuracy, especially for difficult questions, while reading fluency was expected to explain fixation times. Thus, it was of interest to determine whether residual variability in specific cognitive skills, such as reading comprehension or attention problems, would explain some additional variance in viewing times, accuracy, and efficiency.

Control students and those with only attention difficulties performed somewhat better in task-oriented reading, particularly with difficult questions, than students with reading difficulties and comorbid attention and reading difficulties, who also performed less well than the control participants in several cognitive measures. Consequently, a strong g-factor was identified from the cognitive measures on which reading skills and attention difficulties were strongly loaded (Laasonen et al., 2020). The g-factor directly explained 67% of the accuracy (cf. Moehring et al., 2016), indicating the high importance of general cognitive ability in locating and encoding relevant semantic content. The mediation effects from cognitive skills to efficiency via viewing times were modest, as the g-factor explained 10% of the overall efficiency, and reading fluency explained 15%. Task difficulty induced multidimensionality in explaining the efficiency outcome, as the g-factor directly explained efficiency in the more difficult questions (14% of variance). These results indicate that high reading fluency and general cognitive ability explain efficiency only modestly; therefore, reading strategies should be specifically targeted in reading instruction. This view is in line with a large body of literature demonstrating that explicit reading comprehension and strategy instruction is highly effective (see, e.g., Berkeley et al., 2010).

The results of the present study indicate that general cognitive ability plays an important role among school-age learners (i.e., sixth grade, at approximately 12 years old) in obtaining the right solutions for given problems (cf. Laasonen et al., 2020; Moehring et al., 2016). It thus seems likely that cognitive skills typically develop concurrently, so gross deviations between, for example, verbal and visuospatial skills are rare (Ramsden et al., 2011). However, in our study, it is possible that the latent g-factor well captured the common variance in basic cognitive skills, but these skills may not be highly correlated with higher-level literacy skills. Previous

studies (Mañá et al., 2017; Vidal-Abarca et al., 2010) have shown that complex task-oriented reading places special demands on metacognitive monitoring in adolescents. In addition, Kannianen et al. (2019) found only a 14% explanatory power for nonverbal reasoning in explaining overall internet reading proficiency, which also consists of higher-level literacy activities such as reading multiple documents and synthesizing information into short written text. In line with this, the less strategic aspect of performance in our study (i.e., accuracy) was better predicted by general cognitive ability than the presumably more strategic skill of efficiency was.

The present study results add to our knowledge about the generic cognitive mechanisms that underlie task-oriented reading. First, general cognitive ability seems to specifically support the semantic comprehension of text and its maintenance in working memory, which is crucial for obtaining high accuracy in task-oriented reading (Moehring et al., 2016). Instead, the selection of what to read and to what depth, which is crucial for efficiency, may depend on the metacognitive control of behavior and trained expertise, as it is potentially a more malleable aspect of task-oriented reading (Kempe et al., 2011). Supportive of this stance are past findings that intelligence is not a significant predictor of response to reading interventions (Stuebing et al., 2009) and that explicit reading comprehension and strategy instruction are highly effective (Berkeley et al., 2010).

## Pedagogical implications

Regarding the mastery of the relatively simple task-oriented reading tasks studied here, the present results indicate that learning difficulties pose no additional burden other than what is predicted by general cognitive ability and reading fluency. Task-oriented reading involves multiple aspects that require explicit reflection and practice, such as what the minimum requirements of the task at hand are, how and where one would obtain the required information, and what to do with the information.

In practice, such evaluation and control routines (Rouet, 2003) may become an integral part of one's literacy skills. The results of the present study suggest that students with relatively low cognitive skills may also obtain good efficiency in task-oriented reading. However, the results also indicate that low cognitive ability poses a greater challenge for comprehension than for efficient reading. Therefore, basic task-oriented reading skills should first be learned through easy fact-finding tasks before progressing to tasks that require more semantic integration and interpretation.

Finally, students' apparent inability to strategically choose not to read an irrelevant paragraph raises concerns about the quality and scope of information literacy education in elementary schools in Finland, even though the country has a highly competent education system (OECD, 2019). On this basis, it is justified to suspect that task-oriented reading requires more educational attention on a global scale.

## Limitations

The results of the present study may be limited to relatively simple forms of task-oriented reading. For example, cues about the relevance of the paragraphs were directly

given in titles in a keyword-like manner, and the answers to easy questions were simple facts, such as numbers. This contrasts with previous research on more complex task-oriented reading requiring, for example, writing synthesized summaries of information gathered from multiple documents (see, e.g., Kanninen et al., 2019). Specific cognitive skills and previous knowledge may be more important in such complex literacy activities. Relatedly, the present study was conducted with adolescents with and without learning disabilities. This limits the ability to draw strong conclusions concerning the theoretical models of task-oriented reading, which are founded on data collected mostly from adolescents or adult participants with no such disabilities. For instance, in the tasks studied here, most adults might be able to strategically choose not to read irrelevant paragraphs.

The process of continuously regulating one's reading depth according to text relevancy needs to be further examined. At the micro level, this process might be modeled as a continuous process of successive fixation durations and scanpaths as a function of word and sentence relevancy. However, due to the use of a small font size, this present study's dataset is not easily suited for such a precise analysis. Instead, the present dataset may be further used to model individual differences in macrolevel reading strategies. However, such a study would first need to handle several data processing challenges, such as how to separate skimming and first-pass reading. In addition, future studies should investigate the role of children's task model quality on their task-oriented reading (Ayroles et al., 2021) and should also consider including the time spent on reading the task assignment as a part of the efficiency measure.

The descriptive and supplementary analyses revealed several group and conditional differences. According to the SEM results, such specific effects (e.g., the difference between easy and difficult tasks and specific cognitive skills) were small compared to more general interrelations in the data (e.g., g-factor and overall viewing times). This present study demonstrates that SEM can be used to detect generic factors that underlie purposeful reading that may easily go unnoticed if only traditional analyses are conducted.

## Conclusions

According to the present study results, (a) general cognitive abilities contribute strongly to comprehension during task-oriented reading and (b) the continuous regulation of one's reading depth according to local variations in text relevancy is a default strategy for obtaining high efficiency in task-oriented reading. Finally, students with learning difficulties performed well in efficiently finding answers to simple fact-finding tasks. However, they had difficulty in providing correct answers to more difficult tasks, which is expected given their somewhat lower general cognitive ability. However, all students, irrespective of their general cognitive ability, seemed able to learn more efficient reading strategies.

## Appendix

See table 2



**Table 2** Correlation matrix.

	AC	EF	FR	FI	FK	RF	AD	RC	VOC	RM	BS	DS	MD	WLI	AS	VA
Accuracy (AC)	1															
Efficiency (EF)	0.30	1														
Fixation on relevant paragraphs (FR)	-0.06	-0.67	1													
Fixation on irrelevant paragraphs (FI)	-0.22	-0.72	0.52	1												
Prior knowledge (PK)	0.10	0.02	-0.11	0.11	1											
Reading fluency (RF)	0.40	0.46	-0.40	-0.43	0.10	1										
Attention deficit (AD)	-0.31	-0.14	0.01	0.13	-0.01	-0.35	1									
Reading comprehension (RC)	0.45	0.22	-0.28	-0.22	0.07	0.47	-0.38	1								
Vocabulary (VOC)	0.46	0.27	-0.21	-0.16	0.07	0.39	-0.19	0.51	1							
Raven matrices (RM)	0.28	0.04	-0.11	0.03	0.11	0.31	-0.29	0.42	0.29	1						
Block design (BS)	0.17	0.01	0.01	-0.05	0.12	0.27	-0.21	0.24	0.32	0.53	1					
Digit span (DS)	0.41	0.25	-0.16	-0.25	0.00	0.42	-0.17	0.33	0.38	0.31	0.17	1				
Memory for designs (MD)	0.34	-0.02	0.00	0.11	0.04	0.13	-0.28	0.27	0.12	0.36	0.35	0.10	1			
Word list interference (WLI)	0.27	0.32	-0.28	-0.24	0.02	0.32	-0.24	0.34	0.34	0.33	0.13	0.52	0.05	1		
Animal sorting (AS)	0.17	0.11	-0.04	-0.07	0.10	0.30	-0.17	0.19	0.26	0.32	0.24	0.26	0.22	0.26	1	
Visual attention (VA)	0.35	0.17	-0.16	-0.20	0.13	0.41	-0.35	0.36	0.31	0.37	0.31	0.32	0.28	0.19	0.37	1
Symbol search	0.30	0.13	-0.19	-0.11	0.07	0.43	-0.24	0.27	0.18	0.41	0.27	0.26	0.33	0.16	0.40	0.34

Abbreviations: C = Control; AD = attention difficulties; RD = reading difficulties; CM = comorbid reading and attention difficulties; Fix = fixation

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## Declarations

**Ethical Approval** Ethics approval was received from Ethical Board of University of Jyväskylä. Informed consent was derived from participants and their caregivers.

**Informed Consent** Informed consent was derived from participants and their caregivers. All the authors have approved the submission of this manuscript. Access to required parts of data and code may be provided with a reasonable request made to the authors. If open access option will be selected, this work is licensed under a CC BY 4.0 license or other license granting green open access publishing after possible embargo period.

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