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Assessing reading and online research comprehension: Do difficulties in attention and executive function matter?

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ABSTRACT

This study evaluated the relation between sixth graders' ($N = 426$) teacher-rated difficulties in attention and executive function (EF) and their comprehension skills. Reading comprehension was assessed with a multiple-choice task and online research and comprehension (ORC) with a problem-solving task. The analyses were controlled for gender, reading fluency and nonverbal reasoning. To investigate differences in students' performance between the tasks, comprehension skills in the multiple-choice task were also controlled for in the ORC task. Structural equation models showed that teacher-rated attention and EF difficulties were related to students' performance more in the problem-solving task than in the multiple-choice task. After controlling for all the background variables, these difficulties explained 9% of the variance of ORC performance in girls and 4% in boys. These results indicate that for students with attention and EF difficulties the ORC task was more challenging than the reading comprehension task.

1. Introduction

During recent years, the role of technology in reading and learning has increased: over 70% of 15-year-old students in the OECD countries reported using a computer at school (OECD, 2015). School-related work often requires students to complete research tasks on the Internet and to locate, evaluate, synthesize and communicate online information, thereby highlighting the kinds of reading skills that are becoming increasingly important in the age of digitalization (Leu, Kinzer, et al., 2013). This digital turn has resulted in new reading comprehension assessments, alongside paper-and-pencil tests, that target the comprehension skills that students need when accessing the Internet (Coiro et al., 2018; Leu et al., 2015; OECD, 2013).

However, studies focusing on the reading skills needed on the Internet have mainly neglected learners with learning difficulties (see Anmarkrud et al., 2018). Little is known about how students with difficulties in attention and executive function manage to solve problems with online information, even though difficulties in these domains are common (American Psychiatric Association, 2018). Reading research has shown that poor attention (e.g., Cain & Bignell, 2014) and difficulties in EF (for a review, see Follmer, 2018) interfere with comprehension. In addition, low executive functions, such as low shifting and inhibition abilities, have been assumed to overstrain students when they need to switch attention between different online resources and inhibit irrelevant information from relevant information (Schwaighofer et al., 2017). However, as far as we know, it is not investigated whether reading to learn from online information shows the same pattern.

The other unexplored issue is gender differences in online reading among students with attention and EF difficulties. This is an important aspect to investigate for two reasons. First, girls and boys generally differ in their reading performance. Girls significantly outperformed boys in reading in all countries that participated in PISA 2018 (OECD, 2019). Second, students with attention and EF difficulties do not form a homogeneous group, but girls and boys slightly differ in how these difficulties are manifested. Boys seem to exhibit hyperactivity more frequently than girls (Owens et al., 2015), whose difficulties are

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primarily related to inattention (Staller & Faraone, 2006). However, we do not know if girls' and boys' differences in the manifestation of these difficulties associate differently in their performance when reading on the Internet.

In this study, we investigated how attention and EF difficulties were related to students' online research comprehension performance in an everyday, regular classroom context and, therefore, students' attention and EF difficulties were measured with informant-based teacher ratings. In particular, we examined how teacher-rated difficulties in attention and EF affect girls' and boys' reading comprehension measured with a multiple-choice task, and online research and comprehension measured with a problem-solving task. The study aims to provide knowledge that helps teachers to better understand the obstacles students with attention and EF difficulties face when reading to learn from online information.

2. Theoretical frame

2.1. Reading comprehension

Reading comprehension refers to the process where readers construct and integrate word meanings to comprehend a written text (Perfetti & Stafura, 2014). According to the construction-integration (CI) model (Kintsch, 1998; Kintsch & Rawson, 2005) meaning-making involves building a representation at three levels: 1) linguistic representation, 2) a textbase model, and 3) a situation model. On the first level, readers build a linguistic representation by decoding letters to understand single words. On the second level, readers construct a textbase model from the linguistic input by combining the word meanings and, further, interrelating these meanings of the text to form a microstructure. This kind of semantic analysis continues with recognition of the wider topics contained in the whole text that help the reader to build a macrostructure. These two structures form the textbase model, although at this point it constitutes only a shallow understanding of the text. Finally, to build a deeper understanding of the text, readers need to construct a situational model by integrating the textbase information with their prior knowledge (Kintsch, 1998).

Whereas the CI-model focuses on mental processes of reading comprehension, other models focus more on "the identification of component skills" explaining reading comprehension (Kendeou et al., 2016). For example, according to the Simple View of Reading (Hoover & Gough, 1990), reading comprehension consists of two main component skills: decoding and language comprehension. The development of effective and automatized basic decoding skill increases reading fluency, i.e., readers' ability to read text accurately and rapidly (National Reading Panel, National Institute of Child Health, & Human Development, 2000), which has been seen as a limiting factor on reading comprehension (Perfetti & Stafura, 2014). When reading fluency has become automatized, readers can shift their attention from word recognition to comprehending the text (Fuchs et al., 2001).

These theoretical models of reading comprehension also specify inferential processes as an integral component of reading comprehension (Kendeou et al., 2016). Accordingly, the role of nonverbal reasoning in reading comprehension increases when students have reached a sufficient level of literacy skills (e.g., Adlof et al., 2010). Reasoning skills are especially highlighted when students are working with expository texts on less familiar topics (Kintsch & Rawson, 2005) or need to answer comprehension questions that require critical thinking and problem solving (Adlof et al., 2010). In addition, component skills, such as prior knowledge (referring to topical knowledge; Bråten et al., 2013; Tarchi, 2010) and working memory (Sesma et al., 2009) have also been an area of interest in literacy research.

2.2. Online research and comprehension

Traditional literacy skills form a critical foundation for successful reading when solving problems with online information (Kanniainen et al., 2019). However, the Internet as a complex reading environment makes additional demands on the reader, as illustrated in the online research and comprehension model (Kiili et al., 2018b; Leu, Kinzer, et al., 2013). The online research and comprehension (ORC) model defines online reading as a self-directed text construction process when seeking answers to questions on the Internet. At least five processes occur when conducting online research: 1) identifying the question, 2) locating information, 3) evaluating information, 4) synthesizing information, and 5) communicating information.

ORC is a problem-based reading process that starts with *identifying meaningful questions* that direct students' subsequent engagement with online texts and tools (Owens et al., 2002). To answer questions, students need to *locate* relevant information by formulating appropriate search terms for entry into a search engine (Guinee et al., 2003). To ensure the appropriateness of the information yielded, students are required to *evaluate* its credibility (Flanagin & Metzger, 2008). A recent study found that the evaluation of a credible online resource requires different abilities than the evaluation of a questionable online resource (Kiili et al., 2018b); moreover, for students, *questioning credibility* is more difficult than *confirming credibility* (Kiili et al., 2018a; Pérez et al., 2018).

Before *synthesizing* information across different online texts (Cho & Afflerbach, 2015), students first need to make sense of single online texts by *identifying main ideas* (Kiili et al., 2018b). To produce a high-quality synthesis, students explore different viewpoints and compare and contrast texts (Rouet, 2006). Finally, at least in the school context, students are often instructed to *communicate* and interact with each other by sharing their learning outcomes via different kinds of communication tools, such as social networks, emails, or writing tools (Leu, Forzani, et al., 2013). The present study drew upon the ORC model (Leu, Kinzer, et al., 2013), and the ORC assessment used in this study was built on the construct of online research and comprehension. This study extends the previous research on ORC skills by focusing on the challenges students with attention and EF difficulties face online.

2.3. Attention and executive function difficulties

The present study conceptualizes difficulties in the attention and executive function (i.e., executive functions, executive functioning) by drawing on the theories of attention (Mirsky et al., 1999) and EF (Barkley, 1997, 2012; Miyake et al., 2000). EF is an umbrella term for the coordination of cognitive processes that support goal-directed behavior (Barkley, 2012), whereas attention refers to focusing, sustaining, and shifting attention (Mirsky et al., 1999). The basic cognitive processes of EF also involve the previously mentioned ability of shifting attention and, in addition, abilities of inhibition and updating of working memory contents (Miyake et al., 2000).

Difficulties in attentional processes, such as *focusing* and *sustaining attention*, may be seen as difficulties to focus on instructions (i.e., directing attention) and to work for a long time (i.e., sustaining attention; Klenberg et al., 2010). Difficulties in *shifting attention* involve difficulties to switch attention between tasks or sources of relevant information, and difficulties in *inhibition* involve reduced ability to purposefully prevent "dominant, automatic, or prepotent responses" (Miyake et al., 2000). Students with difficulties in inhibition are, for example, not able to wait for their turn (i.e., impulsivity) or to stay seated (i.e., hyperactivity) or to inhibit external distractions (i.e., distractibility; Klenberg et al., 2010). *Updating* information in working memory enables operation at a higher level of EF, which is required in functions, such as planning and nonverbal reasoning that are built on basic cognitive processes (Diamond, 2013). Difficulties in higher level of EF may be seen as difficulties to start working without extra supervision (i.e., initiative), plan one's actions in advance (i.e., planning), accomplish tasks efficiently (i.e., execution of action), or evaluate one's own performance (i.e., evaluation; Klenberg et al., 2010).

The aforementioned attention and EF processes are important for managing goal-directed behavior (Cirino et al., 2018). Previous research has used both performance-based measures and informant-based rating measures to assess various aspects of these processes (for a review, see Toplak et al., 2013). Performance-based measures are usually conducted under clinical conditions, whereas informant-based measures are conducted by evaluating one's performance in everyday, problem-solving situations (Follmer, 2018; Toplak et al., 2013). Thus, these two varying measurement types assess somewhat different aspects of cognitive functioning, and seem to be weakly related to each other (Gerst et al., 2017; Toplak et al., 2013).

In spite of these differences, both measurement types seem to predict students' academic performance. For example, both types have been found to associate similarly to students' reading comprehension (r = 0.32–0.55 versus 0.38–0.55; Gerst et al., 2017). Performance-based measures can provide important information about the efficiency of cognitive processes, such as working memory, in a highly structured environment, whereas rating measures can inform individuals' success in achieving learning goals (Toplak et al., 2013). Teachers' assessments of students' behavior in classrooms can provide an ecologically valid way of evaluating students' difficulties in attention and EF at school (Barkley, 2012). Previous studies have indicated that teacher ratings of difficulties in attention and EF usually form a unidimensional, general factor both in clinical samples (e.g., Toplak et al., 2012) and in nonclinical, community samples (e.g., Caci et al., 2016). In this study, students' difficulties in attention and EF were evaluated with informant-based teacher ratings, as we were interested in how well students with these difficulties performed in everyday, school-related tasks that require them to engage in executive processes.

2.4. Difficulties in attention and executive function in reading and online research comprehension

Difficulties in both attention and EF have been investigated in various reading-related studies. The results have shown that the risk for reading difficulties is high for students with difficulties in attention (Rommelse et al., 2009; Willcutt & Pennington, 2000). Previous research also shows that inattentiveness is a stronger predictor of reading comprehension difficulties than hyperactivity or impulsivity, although this association seems to be mediated by word reading ability, which in turn is a stronger predictor than inattentiveness (e.g., Cain & Bignell, 2014). However, it seems that students with difficulties in attention have challenges in building mental representations beyond word reading ability, since sustaining attention uses a high proportion of their cognitive resources, leaving a smaller proportion for higher-level comprehension (Miller et al., 2013).

Furthermore, EF difficulties have also shown to be associated with reading comprehension at both the elementary and secondary levels (Cutting et al., 2009). Shifting (Kieffer et al., 2013) and planning (Sesma et al., 2009) skills are known to contribute to reading comprehension after controlling for literacy skills such as word reading ability or reading fluency. Inhibition also seems to be associated with reading comprehension (for a review, see Butterfuss & Kendeou, 2018), especially when the measure of inhibition is associated with the memory functions (Borella et al., 2010). Although the various types of EF processes relate to reading comprehension, the common factor of EF seems to predict comprehension over the subprocesses, such as shifting and inhibition (Cirino et al., 2018). Further, the common EF factor was found to be strongly associated with reading comprehension (Cirino et al., 2019).

While the effects of attention and EF difficulties on reading comprehension have been extensively studied, little is known about their role when reading in complex online information spaces where critical evaluation and the use of multiple online resources are at a premium. Some research compares reading comprehension on paper to digital reading comprehension in individuals with attention difficulties (Ben-Yehudah & Brann, 2019; Stern & Shalev, 2013), but focuses only on media conditions. Previous findings also show that students who regularly watched TV and simultaneously surfed on the Internet (i.e. media multitasked) reported more difficulties in situations that required them to shift their attention between multiple tasks and inhibit distractions (Baumgartner et al., 2014).

We also found one small-scale study showing that less successful online readers seem to experience more difficulties with planning and executing actions, when they ran into a gap in their knowledge, than successful online readers (Cho et al., 2018). In addition, a few studies have been done on the ORC of individuals with reading difficulties (Andresen et al., 2018; Kanniainen et al., 2019; Castek et al., 2011; Henry et al., 2012) and intellectual disabilities (Salmerón, Fajardo, & Gómez-Puerta, 2018). However, to our knowledge, the present study is the first attempt to explore the associations of difficulties in attention and EF with students' ORC performance.

2.5. Gender differences

Historically, attention difficulties have been regarded as less common in girls than boys; however, the gender difference has been found to be smaller than expected (Owens et al., 2015). Girls often receive lower ratings for hyperactivity, impulsivity and inattention (for a review, see Gershon, 2002), although these differences seem mainly to concern hyperactivity and impulsivity (Owens et al., 2015). Rater background seems to play a role in the assessment of attention difficulties (Gershon, 2002). It might be that teachers pay more attention to disruptive behavior than inattentive behavior, which could explain why girls' difficulties are more often under-identified (e.g., Meyer et al., 2017). The rating inventories tend to better identify difficulties in boys than in girls (Skogli et al., 2013).

In addition, it has been shown that boys with attention difficulties are more likely to be identified as having reading difficulties than girls with attention difficulties (Biederman et al., 2002). However, research has shown that girls with attention difficulties have more difficulties in full-scale IQ performance (verbal and nonverbal) than boys with attention difficulties (Gershon, 2002). Differences between girls and boys also exist in the identification of reading difficulties: dysfluently reading boys are more frequently identified than dysfluently reading girls (for a review, see Quinn, 2018). While convincing evidence that girls outperform boys in reading fluency and reading comprehension has been presented (e.g., Logan & Johnston, 2009; Torppa et al., 2018), less research exists on the effects of gender on ORC skills. Only some evidence favoring girls in these skills has been found (Kanniainen et al., 2019; Salmerón, García, & Vidal-Abarca, 2018).

2.6. Present study

This study explored 1) the association of teacher-rated difficulties in attention and executive function with students' performance in reading comprehension assessed with a multiple-choice task, and with online research and comprehension assessed with a problem-solving task; and 2) whether the associations were similar for girls and boys. First, as a preliminary step, we examined the factor structure of the teacher ratings of girls' and boys' difficulties in attention and EF, since we expected to find gender differences.

Second, teacher-rated attention and EF difficulties in girls and boys were investigated in relation to their performance in the multiple-choice task, controlling for the effect of gender, reading fluency and nonverbal reasoning. Finally, these difficulties were studied in relation to students' performance in the problem-solving task by gender. In addition to controlling for the above-mentioned background variables, comprehension skills in the multiple-choice task was also controlled for to determine the association of difficulties in attention and EF with what is unique to ORC.

Previous literature (e.g., Butterfuss & Kendeou, 2018; Cirino et al., 2019; Cutting et al., 2009; Miller et al., 2013) shows that students' difficulties in attention and EF associate with their reading comprehension, but lacks information of the effects of these difficulties on their ORC performance. It is shown that students with reading difficulties (Kanniainen et al., 2019) and intellectual disabilities (Salmerón et al., 2018) need support when reading online. Completing the problem-based ORC assessment task requires coordination of multiple online reading processes, such as critical evaluation of information and synthesizing information within and across different online resources. These kinds of complex reading processes may be overloading for students with low executive functions (Schwaighofer et al., 2017), especially, when they need to navigate between different online resources and online reading processes. Reading comprehension measures typically assess comprehension of linear texts, but working with multiple online texts goes beyond processing a single linear text (Cho & Afflerbach, 2017).

Saying this, we hypothesized that the difficulties in attention and EF would play a greater role in the ORC task than in the reading comprehension task (Hypothesis 1). As previous studies suggest that teacher ratings of difficulties in attention and EF usually form a unidimensional, general factor, we did not set any particular hypothesis on a role of the difficulties in subprocesses of EF, such as low shifting and inhibition abilities. Based on previous research, girls seem to outperform boys in reading skills (e.g., Kanniainen et al., 2019; Torppa et al., 2018), and reading difficulties are less frequently identified in girls than boys (e.g., Quinn, 2018). Thus, gender differences in difficulties in attention and EF were expected to contribute less to girls' than boys' performance in both of the comprehension tasks (Hypothesis 2).

3. Method

3.1. Participants

Participants were 426 sixth-grade students (207 girls, 219 boys) recruited from eight elementary schools in Central Finland during the years 2014–2015. We first contacted principals of the schools who further forwarded the request to the teachers of sixth graders. Thus, all the school classes participated voluntarily. The schools were located in both rural and sub-urban areas. All participants were aged between 12 and 13 years ($M = 12.34$, $SD = 0.32$) and were taught in mainstream classrooms following the Finnish National Curriculum (The Finnish National Board of Education, 2004). All participating students spoke Finnish as their primary language. The ethical statement for the study was received from the university Ethical Committee, and guardians signed a written consent for their children's participation in the study.

3.2. Comprehension tasks

3.2.1. Reading comprehension

A group-administered reading comprehension subtest drawn from the standardized Finnish reading test battery ALLU (Lindeman, 1998) was used to assess students' comprehension skills. In this paper-and-pencil assessment, the students were required to silently read a two-page (557 words) expository text containing instructions for consumers. These instructions included information on, for example, consumer protection policy and returns and exchanges of consumer goods. The expository texts of the test battery ALLU are factual and descriptive texts, and are comparable to traditional textbook texts (Lindeman, 1998).

The students answered 12 multiple-choice (four options) questions, which represented five categories: 1) detail or fact (one question), 2) cause-effect or structure (one question), 3) conclusion or interpretation (four questions), 4) concept or phrase (three questions), and 5) main idea or purpose (three questions). The text was available when responding to the questions. One point was given for each item correctly responded to, and thus the maximum score was 12 points. A reading comprehension factor was formed based on these twelve items (see Data Analyses section). Cronbach's alpha reliability coefficient was 0.64, and Revelle's omega reliability coefficient was 0.86.

3.2.2. Online research and comprehension

A Finnish adaptation (ILA; see Kiili et al., 2018b) of the Online Research and Comprehension Assessment (ORCA; Leu, Forzani, et al., 2013) was used to measure students' online research and comprehension skills. The ILA assessment consisted of a simulated Internet environment and tasks that measured four areas of ORC skills: 1) locating information, 2) evaluating information, 3) synthesizing information, and 4) communicating information. Neither the ILA nor the original assessment, the ORCA, included a task measuring students' ability to identify important questions, since working on answering a same question ensured standardization of the task and thus reliable analyses and comparison of the students' performance across the skill areas (Kiili et al., 2018b).

The ILA assessment began with a fictitious email containing a task assignment sent to the students by the school principal. In the email, the principal instructed the students to explore the health effects of energy drinks and, further, to write a recommendation with justifications on whether or not an energy drink vending machine should be purchased for the school. To help them to form their recommendation, students were asked to examine four different online resources (two news pages [OR1, OR4], an academic online resource [OR2], and a commercial online resource [OR3]). The ILA assessment was completed in a simulated closed Internet environment where students were prompted through the tasks by two avatar students via a simulated social networking site and a chat message window.

Students were asked to locate two of the online resources (OR2, OR4) by formulating a search query in a search engine. For example, students were asked to locate a web page that informs how energy drinks affect teeth (OR4). When students received the search engine result list, they were asked to distinguish the relevant online resource from the irrelevant ones. The avatar student gave a link to the correct online resource, if a student failed in the locating task. Thus, students could still read and take notes from the relevant resources, and receive credits in the next parts of the task. The two other resources (OR1, OR3) were given.

The avatar prompted students to evaluate two online resources (OR2, OR3) by asking them the following questions: 'Is the author expert on health issues related to energy drinks?; Is the information provided on the web page reliable?; Why do you think so?'. When reading the online resources (OR1–OR4), students were tasked to take notes with their own words with a note taking tool. After taking notes, students were asked to write a summary about what they have learned about the health effects of energy drinks. Students were able to utilize their notes while synthesizing their summary. Finally, students communicated with the principal by composing an email, in which they justified their opinion concerning the purchase of the energy drink vending machine. The overview of the stimulus materials of the ILA is presented in Fig. 1. The flow of the ILA assessment and the scoring rubric for the measured subskills are presented in more detail in the Appendix A. For a more specific description of the content of the online resources used in the assessment, see Kiili et al. (2018b).

Validation of the ILA assessment was performed with confirmatory factor analysis, the results of which reflected the online research and comprehension model (Kiili et al., 2018b). The Kappa values for interrater reliability in the ILA assessment were 1.000 for locating, and varied across the items: for evaluating, the Kappa values ranged from

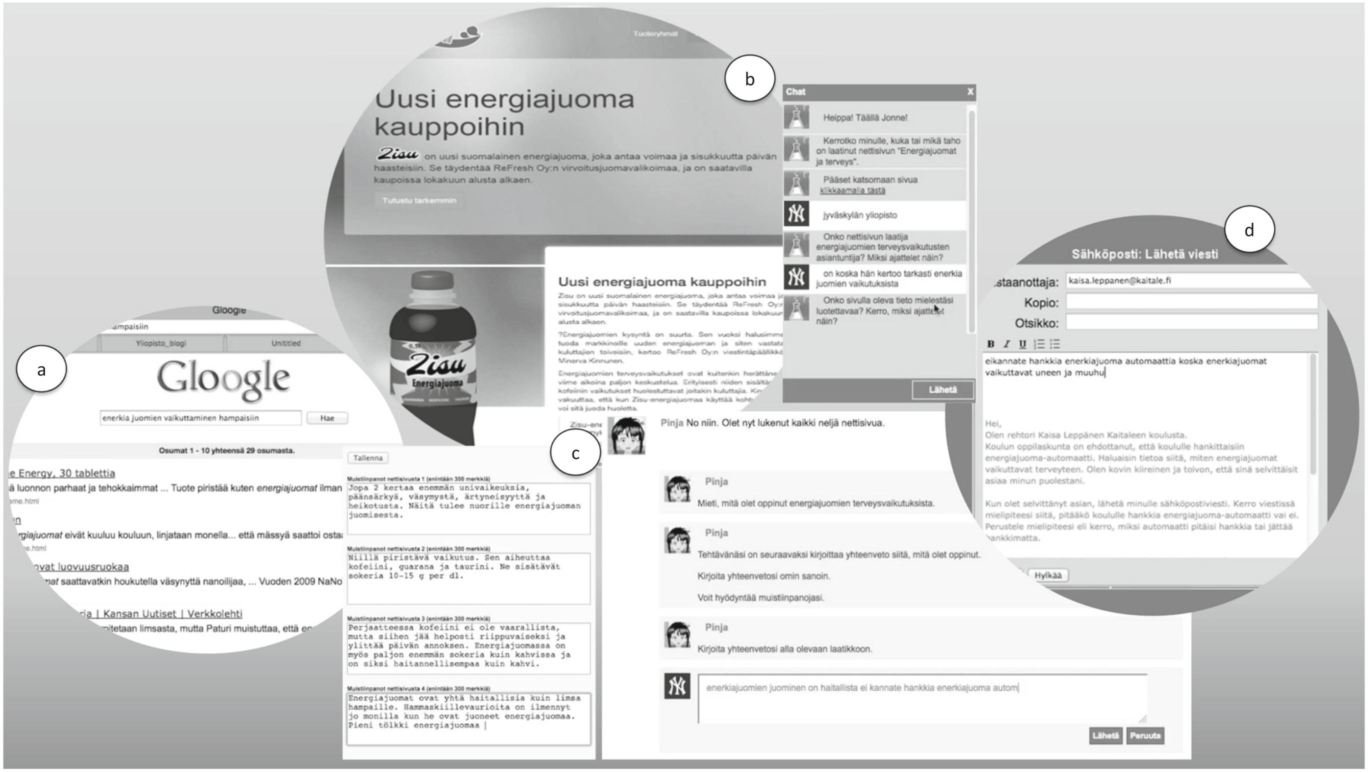

Fig. 1. Screen shots of a) the search engine for locating, b) the commercial online resource and the chat message window for evaluation, c) the note taking tool and the simulated social networking site for synthesis, and d) the mailbox for communication.

Table 1
Subscales of the Attention and Executive Function Rating Inventory (ATTEX) with example items.

Subscale	Example item
1) Distractibility	1. Activities are interrupted by even the smallest external distracter
2) Impulsivity	5. Is clearly impatient
3) Motor hyperactivity	14. Constantly needs manual activities
4) Directing attention	21. Has difficulties focusing attention on instructions given to the whole group
5) Sustaining attention	26. Has difficulties completing tasks
6) Shifting attention	32. Has difficulties noting two things at the same time
7) Initiative	36. Is not able to start on tasks without extra supervision
8) Planning	41. Starts working on tasks without planning
9) Execution of action	45. Needs additional, individual supervision to accomplish tasks
10) Evaluation	55. Has difficulties evaluating own performance, difficulty forming an opinion

Note. Each item has a three-point response scale (0 = not a problem; 1 = sometimes a problem; 2 = often a problem).

0.947 to 0.983, for synthesizing, from 0.784 to 1.000, and for communicating, from 0.722 to 0.939. Cronbach's alpha reliability coefficient for the ILA total score was 0.74.

Students' prior knowledge on the topic of the ILA assessment was measured with a task consisting of seven multiple-choice (each with four response options) questions on energy drinks and their health effects. Since the relatively poor reliability of the prior knowledge measure, it was excluded in the final analysis of this study.

3.2.3. *Differences of the comprehension tasks*

There are clear differences between these two aforementioned comprehension tasks. The first task assesses reading comprehension with a multiple-choice task, whereas the second task assesses online research and comprehension with a problem-solving task. In the reading comprehension task, students worked on a single text with multiple-choice questions, but in the ORC task students worked on multiple texts. In addition, the ORC task requires students to show their comprehension with written responses. Thus, compared to the multiple-choice task, ORC task is more complex requiring different types of skills (e.g., locating relevant information with a search engine, evaluation of information) and formulation of written responses of one's understanding. Both task types are common in daily school life (OECD, 2015).

3.3. *Other measures and materials*

3.3.1. *Teacher-rated difficulties in attention and executive function*

The Attention and Executive Function Rating Inventory (ATTEX; Klenberg et al., 2010) was used to evaluate students' difficulties in attention and EF. Teachers ($N = 24$) were asked, using the ATTEX, to evaluate students' difficulties in the areas of inhibition, attentional control, and execution of action. This rating inventory consists of 55 items, each rated on a three-point response scale (0 = not a problem; 1 =

sometimes a problem; 2 = often a problem). The 55 items form ten subscales: 1) distractibility (q1–4), 2) impulsivity (q5–q13), 3) motor hyperactivity (q14–q20), 4) directing attention (q21–q25), 5) sustaining attention (q26–q31), 6) shifting attention (q32–q35), 7) initiative (q36–q40), 8) planning (q41–q44), 9) execution of action (q45–q52), and 10) evaluation (q53–q55) (Klenberg et al., 2010). These subscales, with an example item from each, are presented in Table 1. In a normative sample of Finnish students (Klenberg et al., 2010), the correlations between the total scores of the ATTEX and the ADHD Rating Scale–IV: School Version (DuPaul et al., 1998) ranged from 0.76 to 0.95 showing a good criterion validity. In this study, Cronbach's alpha reliability coefficient was 0.98.

3.3.2. Reading fluency

Three tests, comprising 1) the word identification test (Lindeman, 1998), 2) the word chain test (Holopainen et al., 2004), and 3) the oral pseudoword text-reading test (Eklund et al., 2014) were used to measure students' reading fluency performance. Based on these three tests, a reading fluency factor was formed (see Data Analyses section). The McDonald's omega, i.e., a model based reliability, was 0.79 (cf. Zhang & Yuan, 2016).

The Kuder-Richardson reliability coefficient for the original version of the word identification test was 0.97 (Lindeman, 1998). The test-retest reliability coefficient for the original version of the word chain test varied between 0.70 and 0.84 (Holopainen et al., 2004). The inter-rater reliability coefficient for the original version of the oral pseudoword text-reading test was 0.95 (Eklund et al., 2014).

3.3.3. Nonverbal reasoning

The Raven's Standard Progressive Matrices (RSPM; Raven, 1998) was used to assess students' ability at abstract reasoning in a visuospatial task appropriate for children over age 11. The full version of the RSPM has 60 items; here, to reduce the burden on students, we used a shortened 30-item version (every second item from the full version). Comparisons of shortened and full versions of the RSPM have shown that shortened versions also produce an adequate estimate of nonverbal reasoning (e.g., Wytek et al., 1984). The number of correct responses formed the participants' total score. Cronbach's alpha reliability coefficient was 0.77.

3.4. Procedure

Data were collected by trained research staff from three group testing sessions, each 45 min long, and one 5-minute individual test session. During the first two group sessions (one reading fluency task was individually administered, see below), students completed the paper-and-pencil tests of reading fluency, nonverbal reasoning, and reading comprehension. In the third group session, the students completed the ILA assessment on laptops after answering the prior knowledge questions. The researchers provided technical assistance with the test application when needed, and students' performance was recorded with a screen capture program and saved as log files. While one half of the class was completing the ILA assessment, the other half completed the individual test session, in which pseudoword text reading was assessed. After the first half had completed the ILA, the groups switched tasks.

3.5. Data analysis

3.5.1. Pre-analyses and goodness-of-fit indices

Descriptive and reliability analyses were performed with IBM SPSS Statistics 24. Multigroup confirmatory factor analyses and structural equation models were conducted using Mplus Version 8. The maximum likelihood robust (MLR) estimator was used both with the model for teacher-rated difficulties in attention and executive function and for reading comprehension assessed with the multiple-choice task, since the pre-analysis revealed some non-normality in the distributions of the observed variables. The weighted least square mean and variance adjusted (WLSMV) estimator was used with the online research and comprehension model, since the ORC variables were ordered categorical. MLR estimation is conducted with standard errors and a χ^2-test statistic that are robust to non-normality (Muthén & Muthén, 1998–2017). WLSMV estimation is conducted with a diagonal weight matrix with robust standard errors and with a mean- and variance-adjusted χ^2-test statistic that uses a full weight matrix (Muthén & Muthén, 1998–2017).

Irrespective of missing values (0%–12%, depending on the variable), such as sickness absences, model parameters were estimated using all the incomplete cases. MLR uses the standard missing-at-random (MAR) approach, which assumes missingness to be a function of the observed covariates and observed outcomes (Muthén & Muthén, 1998–2017). WLSMV also assumes missingness to be a function of the observed covariates but not of the observed outcomes (Asparouhov & Muthén, 2010; Muthén & Muthén, 1998–2017). To ensure acceptable model fit for all models, the following cutoff criteria were applied: χ^2-test ($p > .05$), root mean square error of approximation (RMSEA) < 0.06, Tucker–Lewis index (TLI) and comparative fit index (CFI) ≥ 0.95 and, with the MLR estimator, also the standardized root mean squared residual (SRMR) < 0.08, and, with the WLSMV estimator, also the weighted root mean square residual (WRMR) ≤ 0.90 (Hu & Bentler, 1999; Yu, 2002).

3.5.2. Factorial invariance across gender

To test the assumption of gender differences in teacher ratings of difficulties in attention and executive function, multigroup confirmatory factor analyses (MGCFA) were carried out to test factorial invariance across the groups. The factorial invariance tests were conducted on four levels: 1) configural invariance, 2) weak factorial invariance, 3) strong factorial invariance, and 4) strict factorial invariance (Meredith, 1993). Factorial invariance was achieved if the Satorra-Bentler scaled chi-square difference (SBS$\Delta\chi$2) test (Satorra & Bentler, 2001) was not statistically significant ($p > .05$).

First, on the level of configural invariance, the baseline model (M1) was constructed using the MGCFA of the ten sum scores of the teacher rating scales: 1) distractibility, 2) impulsivity, 3) motor hyperactivity, 4) directing attention, 5) sustaining attention, 6) shifting attention, 7) initiative, 8) planning, 9) execution of action, and 10) evaluation. Next, the MGCFA model of weak factorial invariance (M2) was estimated by constraining all the factor loadings of the ten sum scores to be equal across the gender groups. In the MGCFA model of strong factorial invariance (M3), we also evaluated whether the intercepts were equal across the gender groups. Finally, the MGCFA model of strict factorial invariance (M4) was estimated by constraining the item residuals (error variances) to be equal across the groups in addition to invariant factor loadings and invariant item intercepts. After determining the final structure of the MGCFA model, i.e., M3, the factor scores were saved and included in the structural equation models described below.

3.5.3. Reading comprehension model

The first structural equation model (SEM1) was formed to investigate girls' and boys' teacher-rated difficulties in attention and executive function in relation to their performance in reading comprehension assessed with a multiple-choice task. The above-mentioned saved factor scores for girls' and boys' difficulties in attention and EF were included in SEM1 together with a confirmatory factor analysis (CFA) model, i.e., a measurement model, constructed from the twelve items of the reading comprehension task. The latent variable of reading fluency and the observed variables of gender and nonverbal reasoning were controlled for in SEM1. The reading fluency factor was based on CFA constructed from the three reading fluency tests described earlier.

Finally, we defined a latent interaction term for the gender variable, and entered it into the model. This latent interaction term was formed to find out if girls' and boys' difficulties in attention and EF were differently associated with their reading comprehension performance in the multiple-choice task. The latent interaction term represented the association for boys' attention and EF difficulties, and a specific factor of the residual variance of this interaction term was formed to represent the possible additional association for girls.

3.5.4. Online research and comprehension model

The second structural equation model (SEM2) was constructed to investigate girls' and boys' teacher-rated difficulties in attention and executive function in relation to their performance in online research and comprehension assessed with a problem-solving task. The ORC skills were divided into six factors based on 15 observed variables. The six ORC factors represented the abilities to 1) locate information with a search engine, 2) confirm the credibility of information, 3) question the credibility of information, 4) identify main ideas from a single online resource, 5) synthesize information across multiple online resources, and 6) communicate a well-justified and source-based position via email to a specific audience (see also Kiili et al., 2018b).

These six ORC factors were highly correlated, and thus a second-order factor was derived to capture the common variance across the first-order factors. This measurement model resembled the CFA model found in the study by Kanniainen et al. (2019) in which they evaluated the CFA model with the common second-order factor and the six first order factors against the less restrictive, CFA model with the six first-order factors. When they compared these nested models, a negative correlation between the residuals of questioning credibility and synthesizing was found indicating an inverse relation. This negative correlation was also resembled in the present study.

Next, the saved factor scores of girls' and boys' difficulties in attention and EF were again included in the model, after controlling for gender, reading fluency, and nonverbal reasoning. Comprehension skills in the multiple-choice task were also controlled for in SEM2 by using the saved factor scores of reading comprehension from SEM1. Finally, the latent interaction term representing the association for boys' difficulties in attention and EF, and the specific factor of the residual variance of this interaction term representing the association for girls, were derived to reflect possible differences in their respective ORC performance.

4. Results

4.1. Descriptive statistics

Table 2 shows the descriptive statistics for reading and online research comprehension, reading fluency, and nonverbal reasoning. Descriptive statistics for the teacher-rated difficulties in attention and executive function were calculated for girls and boys separately for all the ten sum scores of the rating scales (Table 3). Overall, teachers rated girls as having fewer difficulties than boys, especially in motor hyperactivity. The correlation matrices for all the variables used in the SEM analyses are presented in Appendices B and C.

4.2. Factorial invariance of teacher-rated difficulties in attention and EF across gender

Factorial invariance across gender was implemented on four levels using the multigroup confirmatory factor analyses (MGCFA) for teacher-rated difficulties in attention and executive function. The final models are presented in Fig. 2. At the level of configural invariance, MGCFA model M1 showed a similar factor structure of teacher-rated difficulties in attention and EF for both girls and boys. The ten sum scores of the teacher-rating scales formed a single general factor of teacher-rated attention and EF difficulties. Examination of the modification indices revealed that the residuals of distractibility and impulsivity, impulsivity and motor hyperactivity, and directing attention and sustaining attention correlated significantly in both gender groups. In addition, the residuals of initiative and evaluation correlated significantly in girls, as did distractibility and motor hyperactivity in boys. The fit indices for this baseline model were: χ^2-test (60) = 136.68, $p < .001$; RMSEA 0.08; CFI 0.96; TLI 0.93; and SRMR 0.05.

At the second level, MGCFA model M2 did not fully display weak factorial invariance of the factor loadings. Based on the modification indices, the factor loadings of motor hyperactivity and sustaining attention were freed, and the model re-estimated. The factor loadings of these two parameters were noninvariant across girls and boys. The fit indices were: χ^2-test (67) = 145.83, $p < .001$; RMSEA 0.07; CFI 0.96; TLI 0.94; and SRMR 0.06. The SBS$\Delta\chi2$ for these two nested models (M1 vs. M2) was 11.17, $df = 7$, $p > .05$. Partial weak factorial invariance was observed.

At the third level, strong factorial invariance of intercepts was not completely achieved in MGCFA model M3. Since the factor loadings of motor hyperactivity and sustaining attention were noninvariant, the intercepts of these variables were also freed. In addition, the intercepts of distractibility and impulsivity were freed based on the residual variances, and the model was re-estimated. The results showed that these intercepts were noninvariant across gender. The fit indices were: χ^2-test (72) = 155.92, $p < .001$; RMSEA.07; CFI 0.95; TLI.94; and SRMR 0.06. The SBS$\Delta\chi2$ for these two nested models (M2 vs. M3) was 9.29, $df = 5$, $p > .05$. Partial strong factorial invariance was found, meaning that the teacher ratings of the difficulties of the students in attention and EF showed slight gender differences. The final level showed that strict factorial invariance could not be established (M3 vs. M4; $SBS\Delta\chi2$ = 94.56, $df = 10$, $p > .000$), and hence the M3 MGCFA models for both girls and boys were selected as the final models (Fig. 2).

4.3. Structural equation model for reading comprehension

The confirmatory factor analyses (CFA) of reading comprehension performance in the multiple-choice task showed that the twelve items of the task formed a single general factor of reading comprehension. The

Table 2
Descriptive statistics of reading and online research comprehension, reading fluency and nonverbal reasoning.

	M	SD	Min.	Max.
Reading comprehension (max. 12 points)	6.91	2.53	1	12
Online research and comprehension (max. 46 points)	22.61	6.97	6	39
Word identification test (max. 80 points)[a]	48.42	9.34	21	80
Word chain test (max. 100 points)[a]	42.81	14.50	11	85
Pseudoword text-reading test (correctly read words/s)[a]	0.70	0.21	0.19	1.36
Nonverbal reasoning (max. 30 points)	22.12	3.74	7	30

[a] Variables used to form a reading fluency factor score.

Table 3
Descriptive statistics of teacher-rated attention and executive function difficulties for girls and boys separately.

Subscale	Girls (N = 205)				Boys (N = 219)			
	M	SD	Min.	Max.	M	SD	Min.	Max.
Inhibition								
1) Distractibility (max. 8 points)	0.40	1.00	0	7	1.72	1.88	0	8
2) Impulsivity (max. 18 points)	0.54	1.74	0	14	2.92	4.26	0	18
3) Motor hyperactivity (max. 14 points)	0.10	0.59	0	7	1.46	2.54	0	14
Attentional control								
4) Directing attention (max. 10 points)	0.67	1.36	0	7	1.95	2.42	0	10
5) Sustaining attention (max. 12 points)	0.27	0.85	0	6	1.98	2.73	0	12
6) Shifting attention (max. 8 points)	0.25	0.85	0	5	1.17	1.94	0	8
Execution of action								
7) Initiative (max. 10 points)	0.41	0.98	0	8	1.82	2.46	0	10
8) Planning (max. 8 points)	0.23	0.75	0	5	1.21	1.93	0	8
9) Execution of action (max. 16 points)	0.68	1.57	0	13	2.46	3.04	0	14
10) Evaluation (max. 6 points)	0.20	0.61	0	5	0.82	1.39	0	6

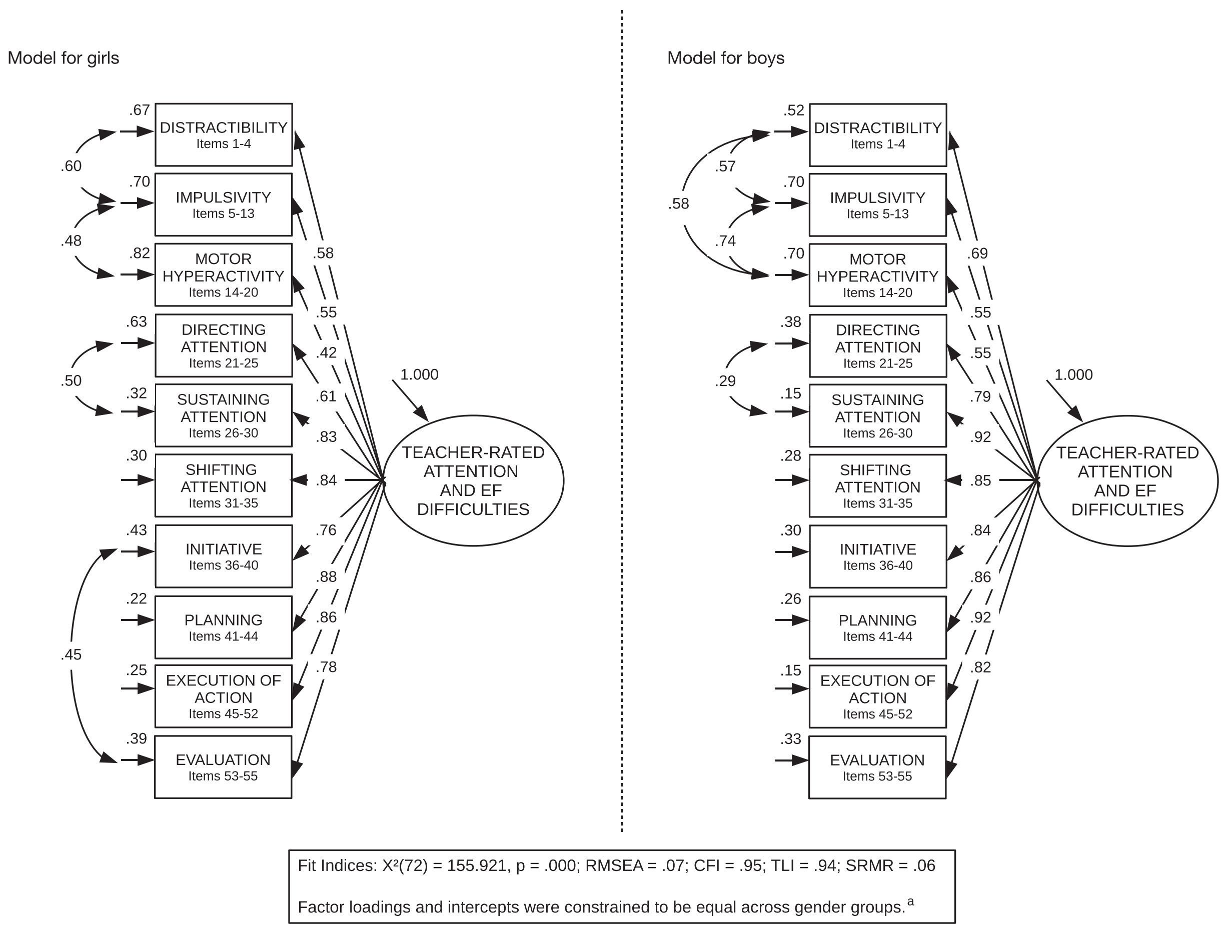

Fig. 2. Multigroup confirmatory factor analysis models (M3) showing the partial factorial invariance of teacher-rated difficulties in attention and executive function (EF) across gender. Notes: Only standardized and statistically significant (p < .05–.001) values are included in the figure. [a]All the factor loadings, except those for motor hyperactivity and sustaining attention, and all the intercepts, except those for distractibility, impulsivity, motor hyperactivity and sustaining attention, were constrained to be equal between the two groups.

factor loadings of this general factor ranged between 4%–24% (0.21–0.49, p < .001). The above-mentioned saved factor scores of the final MGCFA model (Fig. 2) of teacher-rated difficulties in attention and executive function were estimated in relation to the factor of reading comprehension in the first structural equation model (SEM1). The main effect of gender (e.g., differences in means), reading fluency, and nonverbal reasoning were controlled for in the model. The fit indices were: χ^2-test (141) = 166.81, p = .068; RMSEA = 0.02; CFI = 0.98; TLI = 0.97; and SRMR = 0.04. Thus, SEM1 indicated a good model fit.

The results of the reading comprehension model, SEM1 are presented

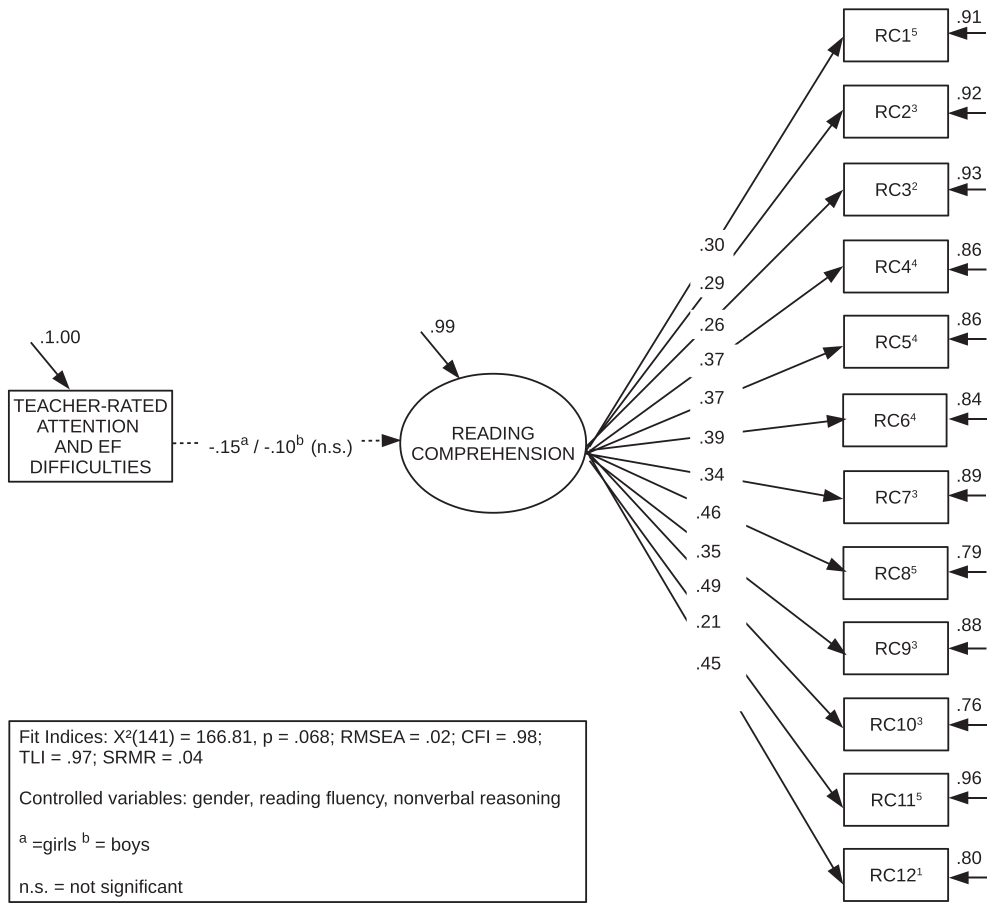

Fig. 3. Structural equation model (SEM1) of the association between students' difficulties in attention and executive function (EF) and their performance in reading comprehension (RC) assessed with a standardized multiple-choice task (ALLU), controlled for the main effect of gender (e.g., differences in means), reading fluency and nonverbal reasoning. Notes: [a] = girls, [b] = boys. All values are standardized, and nonsignificant coefficients ($p > .05$) are indicated with a dotted line. The factor scores of the teacher-rated attention and executive function were saved from the model presented in Fig. 2. [1] = detail or fact; [2] = cause-effect or structure; [3] = conclusion or interpretation; [4] = concept or phrase; [5] = main idea or purpose.

in Fig. 3. For visual clarity, the paths from the controlled variables to reading comprehension are presented as additional information in Appendix D. No statistically significant relation was observed between teacher ratings of students' difficulties in attention and EF and students' performance in reading comprehension assessed with the multiple-choice task, after controlling for the main effect of gender (e.g., differences in means), reading fluency and nonverbal reasoning. Similarly, no interaction effect of gender was observed between teacher-rated difficulties in attention and EF and reading comprehension performance. This means that difficulties in attention and EF were not differently associated with girls' compared to boys' reading comprehension in the multiple-choice task.

4.4. Structural equation model for online research and comprehension

The confirmatory factor analyses of online research and comprehension performance in the problem-solving task showed that a common ORC factor explained 25% (0.50; $p < .001$) of locating; 41% (0.64; $p < .001$) of confirming credibility; 36% (0.60; $p < .001$) of questioning credibility; 69% (0.83; $p < .001$) of identifying main ideas; 61% (0.78; $p < .001$) of synthesizing; and 67% (0.82; $p < .001$) of communicating. Negative correlation between the residuals of questioning credibility and synthesizing was -0.29 ($p < .01$).

Next, the saved factor scores of the final MGCFA model (Fig. 2) of teacher-rated attention and executive function difficulties were re-estimated, but now in relation to the online research and comprehension factor in the second structural equation model (SEM2). Alongside the main effect of gender (e.g., differences in means), reading fluency, and nonverbal reasoning, comprehension skills in the multiple-choice task (saved factor scores from the SEM1) were controlled for in the model. The fit indices were: χ^2-test (207) 265.64, $p = .004$, RMSEA = 0.03; CFI = 0.99; TLI = 0.99; and WRMR = 0.77. Thus, SEM2 fitted the data well.

The main results of the ORC model, SEM2 are depicted in Fig. 4. For visual clarity, the paths from the controlled covariates to ORC are presented in Appendix D. A statistically significant relation was observed between teacher ratings of students' difficulties in attention and EF and students' ORC performance assessed with the problem-solving task, after controlling for the main effect of gender (e.g., differences in means), reading fluency, nonverbal reasoning, and comprehension skills in the multiple-choice task. An interaction effect of gender was observed between teacher-rated difficulties in attention and EF and ORC performance. This means that difficulties in attention and EF were differently associated with girls' and boys' performance in the problem-solving task. After controlling for all the above-mentioned variables, teacher-rated difficulties in attention and EF explained 9% (-0.30; $p < .05$) of the variance of ORC performance in girls and 4% (-0.20; $p < .01$) in boys.

The results supported Hypothesis 1, according to which difficulties in attention and EF played a bigger role in the students' ORC performance, since no association remained between these difficulties and students' reading comprehension performance in the multiple-choice task. Similarly, with respect to Hypothesis 2, no interaction effect of gender was observed between teacher-rated difficulties in attention and EF and reading comprehension performance. As shown above, an interaction effect of gender was found between attention and EF difficulties and

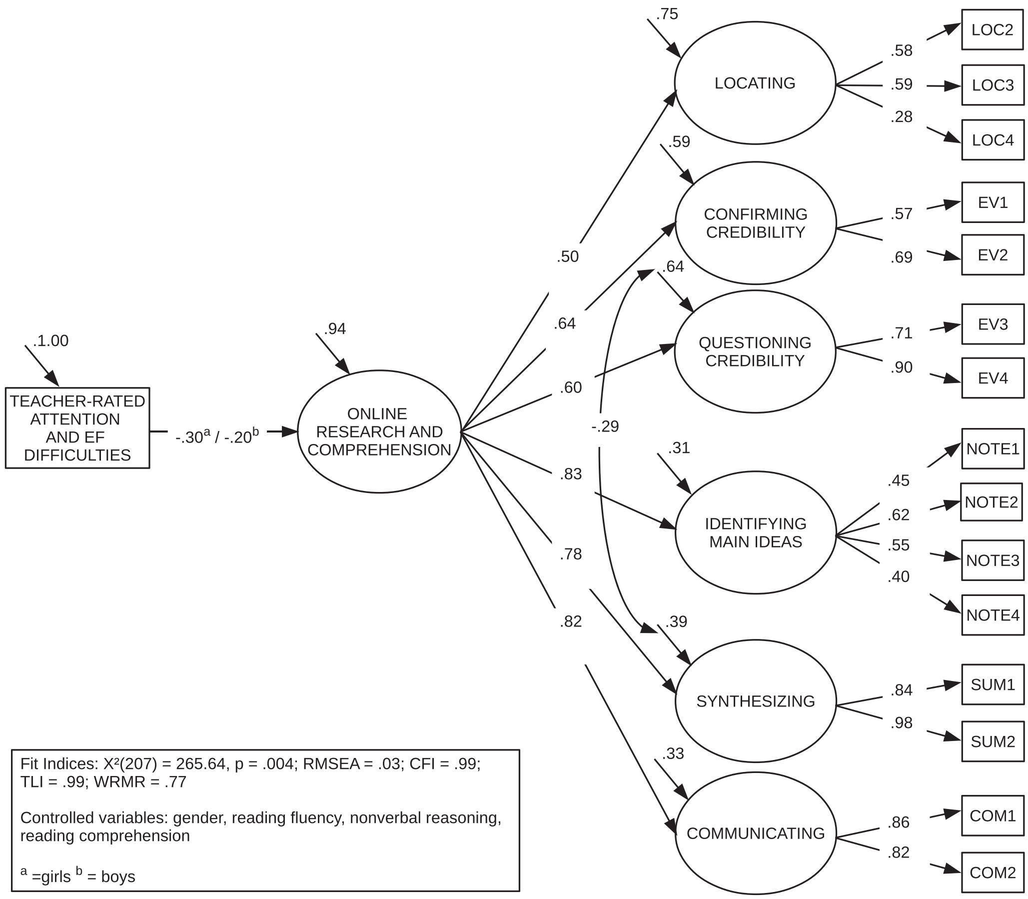

Fig. 4. Structural equation model (SEM2) of the association between students' difficulties in attention and executive function (EF) and their performance in online research and comprehension (ORC) assessed with a problem-solving task (ILA), controlled for the main effect of gender (e.g., differences in means), reading fluency, nonverbal reasoning, and reading comprehension in the multiple-choice task (ALLU). Notes: [a] = girls, [b] = boys. All values are standardized, and only statistically significant (p < .05–.001) coefficients and variances are shown. The factor scores of the teacher-rated attention and executive function were saved from the model presented in Fig. 2, and the factor scores of the reading comprehension from the model presented in Fig. 3.

ORC performance. Contrary to our hypothesis, the gender differences in difficulties in attention and EF had a larger influence on girls' ORC performance than on that of boys.

5. Discussion

Although research on reading skills needed for learning on the Internet has gradually been extended to include students with learning difficulties as well as regular learners, the focus has mainly remained on reading difficulties (Andresen et al., 2018; Kanniainen et al., 2019). However, difficulties related to attention and executive functions may present different kinds of challenges to students' online research and comprehension performance than reading difficulties per se. The present study was undertaken to enhance knowledge on the effects of students' difficulties in attention and executive function on their reading comprehension measured with a multiple-choice task and on ORC measured with a problem-solving task. In addition, we were interested in the role that gender plays in online reading among students with attention and EF difficulties.

Our findings showed that the factor structure of students' difficulties in attention and EF was similar for both genders, thereby forming a one-factor model (Fig. 2). Minor gender differences were observed in the factor loadings of motor hyperactivity and sustaining attention. These findings are consistent with previous research that has frequently shown the nature of teacher ratings of difficulties in attention and EF to be unidimensional (e.g., Caci et al., 2016; Toplak et al., 2012). Further, this accords with earlier observations of girls with attention difficulties, who seem to receive lower ratings in the areas of inhibition (Gershon, 2002) and to be predominantly diagnosed as inattentive rather than hyperactive or impulsive (e.g., Biederman et al., 2002).

Our first hypothesis that students with difficulties in attention and EF would struggle less in the multiple-choice reading comprehension task than in the problem-based ORC task was confirmed. After controlling for the main effects of gender (e.g., differences in means), reading fluency and nonverbal reasoning, students' difficulties in attention and EF did not affect their performance in reading comprehension. However, after controlling the aforementioned background variables and, also, comprehension in the multiple-choice task students' difficulties in attention and EF explained their ORC performance.

One reason for this may be that the ORC task was more complex. Students were required to read information from four different online texts in contrast to reading one text on paper. For example, Cho and Afflerbach (2017) emphasize that creating meaning from multiple online texts goes beyond processing a single linear text. Further, the ORC task also required students to construct meaning in written responses, whereas the multiple-choice comprehension task required students to select an answer from four provided options. Students with difficulties in attention and EF may face problems in meaning construction. Successful writing requires planning, as planning enables writers to construct meanings by organizing their ideas into a meaningful structure (e.g., Flower & Hayes, 1981; McNamara et al., 2019).

The second potential reason may be that students with attention and EF difficulties were more overloaded in the problem-based ORC task than they were in the multiple-choice reading comprehension task. These difficulties rated by teachers included, for instance, difficulties focusing attention on instructions and difficulties completing tasks. In addition, teachers rated difficulties, such as difficulties in noting two things at the same time and difficulties to inhibit external distractions. The more students had these types of difficulties, among others, the more they encountered difficulties in the ORC task. In the ORC task students were required to switch their attention between different online reading processes, such as critical evaluation of information, and synthesizing information across multiple online resources. Further, students were also required not only to switch their attention between the ORC processes but also to shift between different kinds of information locating and communication tools, such as a search engine, a social networking site and a mailbox.

It seems that when using the Internet for solving a problem and representing the solution, attention and EF difficulties play an important role, as readers are required to shift and plan efficiently between different ORC processes and online texts. Sustaining attention to only one process is not enough. Difficulties in attention and EF could even play a bigger role, if texts are also hyperlinked, and contain distractors, such as pop-up advertisements. Thus, future research also needs to investigate the effects of students' difficulties in attention and EF on their ORC performance when accessing the open Internet.

Contrary to our second hypothesis, difficulties in attention and EF were not differentially associated with girls' and boys' reading comprehension in the multiple-choice reading comprehension task after controlling for the main effect of gender (e.g., differences in means), reading fluency and nonverbal reasoning. However, attention and EF difficulties were differentially associated with girls' and boys' performance in the problem-based ORC task. Surprisingly, these difficulties were associated somewhat more with girls' than boys' performance (explaining 9% of girls' and 4% of boys' ORC performance). This indicates that for boys it seems to matter a little less whether they have difficulties in attention and EF, and that their ORC skills are more dependent on other factors.

It remains for future studies to explore possible reasons for the observed gender difference. Future studies could examine whether girls and boys differ in their attitudes towards different types of literacy tasks and materials and if so, do these attitudes play a role in their performance. Additionally, it could be investigated whether the gender difference found in this study exists, if attention and EF difficulties are assessed via performance-based measures, such as measures related to students' shifting and inhibition abilities or working memory. In the present study, we did not include any working memory measures, although demands on working memory may be higher when students read multiple texts compared to reading of a single text (Barzilai & Strømsø, 2018). This is one of the limitations of our study, as such measures can give reliable information of certain cognitive aspects of EFs (see, e.g., Gerst et al., 2017; Toplak et al., 2013).

The present study also has some other limitations that could be addressed in future research. To begin with, the examination of the internal structure of the ATTEX assessment in a nonclinical sample of students may have affected the results. We only found the unidimensional trait of teacher ratings of difficulties. The validity of the ATTEX subscales could be further examined in a mixed clinical sample (see also, Klenberg et al., 2010). In addition, we did not control the teacher effect among the other controlled variables, as teachers can vary in what they consider never, sometimes or often a problem. However, this division of response options is commonly used in the rating scales of EF (see, e.g. Toplak et al., 2013).

Another limitation of the study relates to the somewhat low alpha reliability (0.64) of the reading comprehension measure (ALLU), although it is a part of the widely used nationally standardized (N = 12,897) Finnish reading test battery (Lindeman, 1998). As this measure includes five different types of items (detail or fact; cause-effect or structure; conclusion or interpretation; concept or phrase; and main idea or purpose) that were also unevenly represented (from one to four items per item type), it seems that alpha's assumptions related to tau-equivalence and unidimensionality did not hold (see, e.g., McNeish, 2018; Savalei et al., 2019). Further, the bi-factor based Revelle's omega indicated good reliability (0.86). As the final structural equation model with a good model fit supported only one general reading comprehension factor (see Fig. 3), it remains for the future studies to investigate, if the suitability of Revelle's omega and the somewhat high amount of unexplained variance of the general factor indicate a multidimensional model in a larger sample. In addition, future studies could use a wider range of paper-based reading comprehension measures that would also require critical thinking and problem solving. Finally, we did not measure participants' prior topic knowledge of the reading comprehension task. We attempted to measure prior topic knowledge of the ORC task, but unfortunately, this measure had relatively poor reliability and, therefore, it was omitted from the final analyses.

Despite its limitations, this study broadens understanding of the support that students with difficulties in attention and EF need when they engage in problem-solving tasks on the Internet. First, it is essential to pay more attention to identifying girls' difficulties in attention and EF, as these are not always as obvious as they are in boys, but may nevertheless impede learning, especially in problem-based reading environments, such as the Internet. The present findings also indicate that it might be pedagogically meaningful to divide ORC tasks into more manageable components. In contrast to the open Internet, structured ORC tasks would allow students to focus their attention on just one aspect at a time. This in turn could improve students' performance despite the presence of attention difficulties (see also Raggi & Chronis, 2006). The more restricted online reading environments may be of value in developing and practicing ORC skills.

Finally, another beneficial aspect of using a restricted ORC environment is that it can be designed to contain fewer irrelevant distractors. Previous research has shown that while students with difficulties in attention have a greater need for stimulation, it is important that the stimulation is task-relevant and can help students to inhibit negative distractors (Raggi & Chronis, 2006). It is also worth noticing that modification of technical features alone, such as text window size (Wylie et al., 2018) or line spacing (Stern & Shalev, 2013), is not enough to support students with difficulties in attention and EF. Other more pedagogically oriented features and instructions are needed. In closed ORC environments negative distractors, such as advertisements, can be reduced and replaced with more positive 'distractors', such as prompts and feedback. In sum, greater emphasis should be placed on designing interventions for students with difficulties in attention and EF that support their learning from online information.

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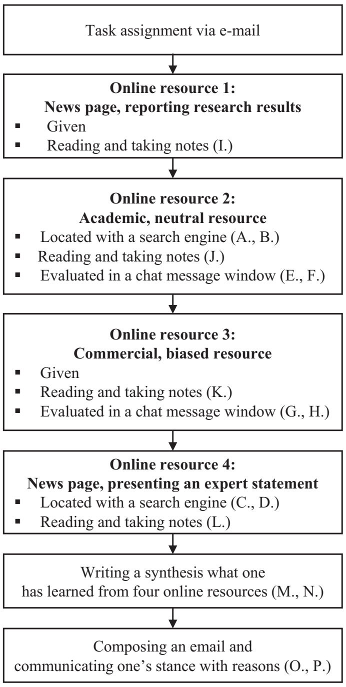
Appendix A. Flow of the ILA assessment and scoring criteria for students' online research and comprehension performance

Flow of the ILA assessment and scoring criteria for students' online research and comprehension performance



	Observed variables	Scores
Locating	A. Formulation of the first search query to locate OR2	0–2 p.
	B. Time spent locating OR2	0–4 p.
	C. Formulation of the second search query to locate OR4	0–2 p.
	D. Time spent locating OR4	0–4 p.
Evaluating	E. Evaluation of authors' expertise in the academic online resource (OR2)	0–3 p.
	F. Evaluation of credibility of information in the academic online resource (OR2)	0–3 p.
	G. Evaluation of authors' expertise in the commercial online resource (OR3)	0–3 p.
	H. Evaluation of credibility of information in the commercial online resource (OR3)	0–3 p.
Synthesizing	I. Identifying main ideas from OR1: News page, reporting research results	0–2 p.
	J. Identifying main ideas from OR2: Academic online resource, answering FAQs on energy drinks with a neutral tone	0–2 p.
	K. Identifying main ideas from OR3: Commercial online resource, including only positive health effects of energy drinks in a press release	0–2 p.
	L. Identifying main ideas from OR4: News page, presenting an expert statement	0–2 p.
	M. Number of online resources used in the summary	0–3 p.
	N. Integration of ideas in the summary: Coherence, coverage, and use of connectives	0–3 p.
Communicating	O. Quality of argumentation in the email: Stance supported by online resources, number of reasons representing different perspectives	0–5 p.
	P. Communicative practices in the email: Awareness of the audience, clear and polite way of expressing oneself	0–5 p.

Note. OR1 = online resource 1; OR2 = online resource 2; OR3 = online resource 3; OR4 = online resource 4. More detailed scoring criteria published by Authors (2018b) are available on request from the first author.

Appendix B. Correlation matrix of teacher-rated attention and executive function difficulties

Measures	ATTEX1	ATTEX2	ATTEX3	ATTEX4	ATTEX5	ATTEX6	ATTEX7	ATTEX8	ATTEX9	ATTEX10
ATTEX1	1.00									
ATTEX2	.77***	1.00								
ATTEX3	.73***	.82***	1.00							
ATTEX4	.63***	.51***	.42***	1.00						
ATTEX5	.73***	.64***	.62***	.79***	1.00					
ATTEX6	.60***	.48***	.46***	.67***	.80***	1.00				
ATTEX7	.55***	.43***	.44***	.72***	.80***	.76***	1.00			
ATTEX8	.61***	.59***	.55***	.62***	.82***	.78***	.73***	1.00		
ATTEX9	.65***	.58***	.58***	.72***	.84***	.78***	.80***	.81***	1.00	
ATTEX10	.57***	.55***	.53***	.60***	.72***	.71***	.70***	.78***	.77***	1.00
RC1	−.12**	−.07	−.07	−.13**	−.08	−.08	−.09	−.04	−.06	−.06
RC2	−.10	−.08	−.07	−.13*	−.13*	−.15**	−.11*	−.12*	−.14*	−.12
RC3	−.07	−.02	−.02	−.17**	−.09	−.08	−.08	−.03	−.05	−.09
RC4	−.14**	−.05	−.06	−.09	−.09	−.12*	−.13**	−.10*	−.12*	−.09
RC5	−.04	.02	.04	−.09	−.01	−.06	−.06	−.02	−.05	−.03
RC6	−.12*	−.09	−.09	−.11*	−.12*	−.20***	−.16**	−.13*	−.17**	−.17**
RC7	−.23***	−.14**	−.13**	−.20***	−.24***	−.23***	−.24***	−.20***	−.21***	−.16**
RC8	−.09	.00	−.05	−.04	−.07	−.10*	−.10*	−.12*	−.12**	−.10*
RC9	−.11*	−.05	−.01	−.15**	−.09	−.10*	−.16**	−.08	−.12*	−.14**
RC10	−.17***	−.13*	−.12*	−.18***	−.19***	−.24***	−.20***	−.22***	−.18***	−.17**
RC11	.01	.07	.06	.02	.01	−.04	.01	−.01	.02	.00
RC12	−.21***	−.11*	−.11*	−.18***	−.20***	−.23***	−.20***	−.20***	−.25***	−.20***
LOC2	−.15**	−.13**	−.15**	−.17***	−.14**	−.12*	−.18***	−.10*	−.16***	−.12**
LOC3	−.14**	−.10	−.10	−.15**	−.18**	−.14*	−.18***	−.16**	−.16**	−.13*
LOC4	−.04	−.04	−.05	−.02	−.02	−.01	.03	.04	−.05	.04
EV1	−.15**	−.09	−.07	−.18***	−.18***	−.17**	−.21***	−.18***	−.16**	−.18***
EV2	−.19***	−.14**	−.14**	−.18***	−.17***	−.16***	−.22***	−.14**	−.18***	−.20***
EV3	−.20***	−.09	−.13**	−.16***	−.21***	−.23***	−.21***	−.19***	−.18***	−.16**
EV4	−.17***	−.11*	−.13**	−.22***	−.21***	−.23***	−.26***	−.18***	−.20***	−.19***
NOTE1	−.13*	−.12*	−.13*	−.14**	−.20***	−.20***	−.24***	−.16**	−.19***	−.17**
NOTE2	−.16**	−.11	−.12*	−.12*	−.16**	−.15**	−.22***	−.17**	−.19**	−.19***
NOTE3	−.14**	−.07	−.09	−.12*	−.13*	−.13**	−.15**	−.11*	−.15**	−.14**
NOTE4	−.18**	−.14**	−.13*	−.11*	−.16**	−.15**	−.16**	−.15**	−.18***	−.16**
SUM1	−.27***	−.18***	−.19***	−.20***	−.22***	−.25***	−.23***	−.21***	−.23***	−.21***
SUM2	−.29***	−.21***	−.19***	−.23***	−.24***	−.25***	−.26***	−.24***	−.26***	−.22***

(*continued on next page*)

(*continued*)

Measures	ATTEX1	ATTEX2	ATTEX3	ATTEX4	ATTEX5	ATTEX6	ATTEX7	ATTEX8	ATTEX9	ATTEX10
COM1	−.30***	−.24***	−.21***	−.31***	−.34***	−.37***	−.35***	−.33***	−.36***	−.32***
COM2	−.26***	−.22***	−.22***	−.29***	−.31***	−.33***	−.32***	−.31***	−.33***	−.31***
RF1	−.12**	.01	−.04	−.24***	−.19***	−.23***	−.24***	−.13**	−.24***	−.14**
RF2	−.29***	−.19***	−.20***	−.28***	−.29***	−.28***	−.26***	−.31***	−.33***	−.23***
RF3	−.16***	−.10*	−.13**	−.17***	−.17***	−.15**	−.16**	−.17***	−.21***	−.15**
NVR	−.33***	−.27***	−.24**	−.42***	−.42***	−.47***	−.43***	−.44***	−.43***	−.41***

Note. ATTEX1–ATTEX10 = subscales of teacher-rated attention and executive function difficulties; RC1–RC12 = items of reading comprehension; LOC2–LOC4 = items of locating; EV1–EV2 = items of confirming credibility; EV3–EV 4 = items of questioning credibility; NOTE1–NOTE4 = items of identifying main ideas; SUM1–SUM2 = items of synthesizing; COM1–COM2 = items of communicating; RF1–RF3 = items of reading fluency; NVR = nonverbal reasoning.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Appendix C. Correlation matrix of reading and online research and comprehension

Measures	RC1	RC2	RC3	RC4	RC5	RC6	RC7	RC8	RC9	RC10	RC11	RC12
RC1	1.00											
RC2	.07	1.00										
RC3	.07	.14**	1.00									
RC4	.14**	.05	.12*	1.00								
RC5	.06	.11*	.10*	.20***	1.00							
RC6	.14**	.12*	.03	.18***	.17***	1.00						
RC7	.16**	.03	.10	.10*	.06	.15**	1.00					
RC8	.04	.17***	.09	.19***	.27***	.25***	.14**	1.00				
RC9	.11*	.06	.08	.14**	.10*	.15**	.19***	.15**	1.00			
RC10	.19***	.14**	.16**	.10*	.17**	.21***	.13**	.22***	.16**	1.00		
RC11	.09	.01	.00	.08	.12*	.07	.06	.16**	.09	.03	1.00	
RC12	.16**	.12*	.12*	.18***	.23***	.10*	.13**	.18***	.10*	.22***	.16**	1.00
LOC2	.04	.09	.11*	.07	.04	.05	.12*	.10*	.11*	.19***	.03	.01
LOC3	.01	.09	.01	.03	.08	.11*	.06	.16**	.09	.16**	.04	.07
LOC4	.10*	.10	.03	−.01	.01	.03	.01	−.02	.04	.07	.01	−.01
EV1	.05	.08	.13**	.15**	.09	.11*	.11*	.15**	.19***	.11*	.08	.12*
EV2	.10*	.11*	.03	.17***	.13**	.21***	.12*	.18***	.12*	.18***	.09	.15**
EV3	.07	.12**	.11*	.11*	.07	.08	.11*	.16**	.10*	.19***	.08	.14**
EV4	.17***	.15***	.09	.13**	.14**	.10*	.16**	.20***	.20***	.18***	.08	.12**
NOTE1	.02	.10	−.01	.07	.02	.11*	.13**	.10*	.17***	.07	.01	.09
NOTE2	.12*	.15**	.12*	.15**	.08	.11*	.11*	.22***	.16**	.20***	.13**	.12*
NOTE3	.12*	.13**	.10*	.15**	.09	.14**	.08	.12*	.10*	.13**	.06	.22***
NOTE4	.08	.16**	.10*	.11*	.02	.08	.03	.18***	.04	.08	−.06	.13**
SUM1	.14**	.19***	.06	.13**	.05	.23***	.11*	.16**	.17***	.16**	.15**	.18***
SUM2	.16**	.23***	.02	.11*	.08	.18***	.09	.14**	.15**	.19***	.08	.20***
COM1	.15**	.27***	.02	.13**	.05	.18***	.16**	.18***	.22***	.19***	.13**	.18***
COM2	.13*	.25***	−.05	.10*	.10*	.20***	.17***	.20***	.20***	.27***	.06	.18***
RF1	.10*	.07	.05	.09	.09*	.16***	.09	.18***	.10*	.22***	.12*	.15**
RF2	.16**	.16**	.12*	.18***	.10*	.17***	.19***	.23***	.18***	.28***	.13**	.25***
RF3	.15**	.13**	.06	.10*	.10*	.09	.10*	.20***	.06	.14**	.05	.19***
NVR	.13**	.21***	.20***	.19***	.17**	.17**	.20***	.19***	.23***	.27***	.06	.23***

Measures	LOC2	LOC3	LOC4	EV1	EV2	EV3	EV4	NOTE1	NOTE2	NOTE3	NOTE4
LOC2	1.00										
LOC3	.22***	1.00									
LOC4	.19***	.15**	1.00								
EV1	.11*	.08	−.01	1.00							
EV2	.11*	.14**	.01	.33***	1.00						
EV3	.10*	.00	.11*	.20***	.16***	1.00					
EV4	.17***	.10*	.07	.26***	.21***	.52***	1.00				
NOTE1	.12*	.14**	.09	.13**	.06	.11*	.09	1.00			
NOTE2	.15**	.12*	.01	.20***	.18***	.22***	.22***	.17**	1.00		
NOTE3	.06	.07	.04	.16**	.19***	.15**	.14**	.21***	.27***	1.00	
NOTE4	.11*	.05	.07	.19***	.13**	.17***	.18***	.15**	.17**	.21***	1.00
SUM1	.26***	.15**	.13**	.22***	.22***	.19***	.17***	.18***	.39***	.32***	.22***
SUM2	.18***	.13**	.07	.17***	.29***	.20***	.23***	.24***	.33***	.31***	.19***
COM1	.18***	.08	.07	.18***	.27***	.25***	.34***	.22***	.27***	.24***	.19***
COM2	.20***	.13**	.12*	.19***	.29***	.21***	.32***	.18***	.25***	.21***	.14**
RF1	.13**	.02	.14**	.03	.19***	.16**	.22***	.06	.22***	.14**	.09
RF2	.17***	.15**	.13*	.13*	.21***	.19***	.24***	.08	.27***	.21***	.19***
RF3	.12*	.07	.17***	.05	.17***	.11*	.17***	.00	.16**	.17***	.15**

(*continued on next page*)

(*continued*)

Measures	LOC2	LOC3	LOC4	EV1	EV2	EV3	EV4	NOTE1	NOTE2	NOTE3	NOTE4
NVR	.14**	.13*	.08	.20***	.16**	.15**	.22***	.19***	.25***	.16**	.14**

Measures	SUM1	SUM2	COM1	COM2	RF1	RF2	RF3	NVR
SUM1	1.00							
SUM2	.71***	1.00						
COM1	.39***	.51***	1.00					
COM2	.40***	.50***	.66***	1.00				
RF1	.17***	.20***	.22***	.26***	1.00			
RF2	.30***	.29***	.32***	.36***	.60***	1.00		
RF3	.21***	.23***	.20***	.25***	.46***	.57***	1.00	
NVR	.23***	.21***	.32***	.30***	.20***	.37***	.17***	1.00

Note. RC1–RC12 = items of reading comprehension; LOC2–LOC4 = items of locating; EV1–EV2 = items of confirming credibility; EV3–EV 4 = items of questioning credibility; NOTE1–NOTE4 = items of identifying main ideas; SUM1–SUM2 = items of synthesizing; COM1–COM2 = items of communicating; RF1–RF3 = items of reading fluency; NVR = nonverbal reasoning.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

Appendix D. The relations of gender, reading fluency, and nonverbal reasoning to reading and online research comprehension

	Reading comprehension	Online research comprehension
	B (SE)	B (SE)
Gender	.01 (.06)	.34 (.04)***
Reading fluency	.39 (.06)***	.21 (.06)***
Nonverbal reasoning	.37 (.06)***	.17 (.05)***
Reading comprehension		.35 (.05)***

Note. All values are standardized.

*** $p < .001$.

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