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Laura Kanniainen

Reading for Learning on the Internet at School Age

The Role of Difficulties with Reading and with Attention and Executive Function

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF EDUCATION AND PSYCHOLOGY

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ABSTRACT

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The aim of this dissertation was to increase our knowledge of the extent to which sixth-grade students' literacy skills (reading fluency, written spelling, and reading comprehension), reading habits, nonverbal reasoning ability, and prior topic knowledge were associated with their online research and comprehension performance. This dissertation also aimed to examine interindividual differences in students' online research and comprehension performance among learners with reading difficulties and/or difficulties with attention and executive function and to evaluate the gender effect in association with learners' performance. These aims were addressed in three original studies (Studies I–III) using data from over 400 Finnish sixth-grade students. Students' online research and comprehension performance was examined with a validated web-based assessment measuring their skills in locating, evaluating, synthesizing, and communicating information. First, the findings showed that reading fluency, written spelling, and reading comprehension as well as reading habits all independently contributed to students' online research and comprehension performance. Comprehension was the strongest predictor. Frequency of reading longer and more vocabulary-rich texts, such as books, blog postings, and ebooks, was associated with students' online research and comprehension performance, but the frequency of reading shorter texts, such as comics and online forum posts, was not. Nonverbal reasoning ability independently contributed to explaining students' online research and comprehension performance, but contrary to expectations, prior topic knowledge did not. Second, learners with reading difficulties and/or difficulties with attention and executive function were more likely to belong to the lower online research and comprehension performance profiles. It is noteworthy that some students performed better than expected based on their deficiencies. Third, on average, girls outperformed boys in online research and comprehension performance, but interestingly, girls with attention and executive function difficulties faced more challenges online than boys with these difficulties. Overall, the findings shed light on elementary school students' online research and comprehension performance and could be used to design supportive pedagogical activities for all learners.

Keywords: digital literacy, information literacy, online research and comprehension, learning difficulty, reading, attention, executive function

TIIVISTELMÄ (ABSTRACT IN FINNISH)

Kanniainen, Laura
Tutkivan nettilukemisen taidot alakoululaisilla: Lukivaikeuksien sekä tarkkaavuuden ja toiminnanohjauksen vaikeuksien merkitys
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Tässä väitöskirjatutkimuksessa tarkasteltiin, miten kuudesluokkalaisten oppilaiden peruslukutaidot (lukusujuvuus, oikeinkirjoitustaito, luetun ymmärtäminen), lukutottumukset, ei-kielellinen päättelykyky sekä aiemmat ennakkotiedot olivat yhteydessä heidän suoriutumiseensa tutkivan nettilukemisen tehtävässä. Lisäksi selvitettiin, miten lukemisen vaikeudet ja/tai tarkkaavuuden ja toiminnanohjauksen vaikeudet olivat yhteydessä oppilaiden suoriutumiseen nettilukutehtävässä sekä arvioitiin mahdollisia sukupuolten välisiä eroja. Väitöskirjatutkimus koostuu kolmesta osatutkimuksesta (Osatutkimukset I–III), joihin osallistui yli 400 suomalaista, kuudesluokkalaista oppilasta. Oppilaiden tutkivan nettilukemisen taitoja eli tiedonhakua, lähteiden kriittistä arviointia, synteesin laadintaa sekä taitoa jakaa oppimaansa muiden kanssa arvioitiin validoidussa, Internetiä simuloivassa tehtäväympäristössä. Tutkimustulokset osoittivat, että oppilaiden lukusujuvuus, oikeinkirjoitustaito, luetun ymmärtäminen ja lukutottumukset olivat yhteydessä oppilaiden tutkivan nettilukemisen suoriutumiseen. Näistä merkittävin selittäjä oli oppilaan luetun ymmärtämisen taito. Lukutottumuksista erityisesti pitkien, kielellisesti rikkaiden tekstien, kuten kirjojen, e-kirjojen ja blogien, lukeminen oli tärkeää. Lyhyempien tekstien, kuten sarjakuvien ja keskustelupalstaviestien, lukeminen sen sijaan ei ollut yhteydessä oppilaiden tutkivan nettilukemisen suoriutumiseen. Muista tiedoista ja taidoista ei-kielellinen päättelykyky selitti oppilaiden suoriutumista nettilukutehtävässä, kun taas aiemmat ennakkotiedot tehtävän aiheesta eivät olleet yhteydessä oppilaiden suoriutumiseen. Oppilailla, joilla oli lukemisen ja/tai tarkkaavuuden ja toiminnanohjauksen vaikeuksia, oli haasteita nettilukutehtävässä. Huomionarvoista on kuitenkin se, että joukossa oli myös oppilaita, jotka oppimisvaikeuksistaan huolimatta suoriutuivat nettilukutehtävässä keskimääräisesti tai jopa keskimääräistä paremmin. Lisäksi tytöt pärjäsivät poikia paremmin nettilukutehtävässä. Toisaalta tytöillä, joilla oli tarkkaavuuden ja toiminnanohjauksen vaikeuksia, oli enemmän haasteita nettilukutehtävässä kuin vastaavia vaikeuksia omaavilla pojilla. Tutkimustulokset lisäävät ymmärrystä alakoululaisten tutkivan nettilukemisen taidoista ja tuloksia voidaan hyödyntää tukitoimien suunnittelussa.

Avainsanat: digitaalinen lukutaito, informaatiolukutaito, tutkiva nettilukeminen, oppimisvaikeus, lukeminen, tarkkaavuus, toiminnanohjaus

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Tampere, April 2022
Laura Kanniainen

LIST OF ORIGINAL PUBLICATIONS

This dissertation is based on the following original publications:

Study I
Kanniainen, L., Kiili, C., Tolvanen, A., Aro, M., & Leppänen, P. H. (2019). Literacy skills and online research and comprehension: struggling readers face difficulties online. *Reading and Writing, 32*(9), 2201–2222. https://doi.org/10.1007/s11145-019-09944-9

Study II
Kanniainen, L., Kiili, C., Tolvanen, A., Aro, M., Anmarkrud, Ø., & Leppänen, P. H. (2021). Assessing reading and online research comprehension: Do difficulties in attention and executive function matter?. *Learning and Individual Differences, 87*, 101985. https://doi.org/10.1016/j.lindif.2021.101985

Study III
Kanniainen, L., Kiili, C., Tolvanen, A., Utriainen, J., Aro, M., Leu, D. J. & Leppänen, P. H. (2022). Online research and comprehension performance profiles among sixth-grade students, including those with reading difficulties and/or attention and executive function difficulties. *Reading Research Quarterly*, pp. 1–23. https://doi.org/ 10.1002/rrq.463

As an author of this doctoral dissertation, I have considered the comments and instructions given by the co-authors and contributed to the aforementioned original publications as follows: a) participation in planning the study design and collecting the data, b) implementation of data analyses, c) writing of the manuscripts of the three original publications, and d) administering the review processes of the original publications

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1 INTRODUCTION

Learning to surf the Internet, fascinating as it is to children, is one thing. Reading to learn from online information is quite another. In the last two decades, researchers have made advances in our understanding of how readers learn from online information (Brand-Gruwel et al., 2009; Cho & Afflerbach, 2015; Coiro & Dobler, 2007; Leu et al., 2019). These years have also yielded remarkable progress in assessing the reading practices and skills needed in a modern society (Fraillon et al., 2014; Fraillon et al., 2019; Mullis et al., 2017; Office for Economic Co-operation and Development [OECD], 2013). This is important, as the role of technology in reading and learning has also increased in the school context. Thus, online research and comprehension skills, such as locating, evaluating, synthesizing, and communicating information, are required (Leu et al., 2004; Leu et al., 2019). For instance, 74% of adolescents reported being taught to locate information using information and communications technologies, and 65% reported being taught to evaluate the trustworthiness of the information at school (International Association for the Evaluation of Educational Achievement [IEA], 2019). However, learners who are ill-equipped to confront these kinds of new skill demands in web-based reading environments may face difficulties when reading for learning on the Internet.

Hence, the main objective of this dissertation thesis was to shed light on elementary school students' online research and comprehension performance. Specifically, it aimed to increase our knowledge of the extent to which sixth-grade students' literacy skills (reading fluency, written spelling, and reading comprehension), reading habits, nonverbal reasoning ability, and prior topic knowledge were associated with their online research and comprehension performance. This research also examined interindividual differences in online research and comprehension performance among learners with reading difficulties and/or difficulties with attention and executive function. Finally, it aimed to evaluate the gender effect in association with learners' online research and comprehension performance, including those with learning-related difficulties. The following sections offer detailed definitions of and the rationale behind these objectives.

1.1 From a simple view of reading towards online research and comprehension in complex web-based environments

Before surfing and reading for learning on the Internet, learners need to be able to read and write. Thus, traditional literacy skills seem to form the foundational layer needed for learners to become literate in web-based reading environments. Based on the Simple View of Reading (Duke & Cartwright, 2021; Gough & Tunmer, 1986; Hoover & Gough, 1990; Hoover & Tunmer, 2018), reading comprehension consists of two main skill components: decoding/word recognition and linguistic/language comprehension. Letter–sound decoding ability enables readers to recognize single words by converting letters into spoken word representations and, in written spelling, again to convert words back to the letter strings (Snowling & Hulme, 2005). Successful word recognition and written spelling strengthen orthographic representations of words (Perfetti & Stafura, 2014). Linguistic or language comprehension refers to the readers' ability to understand language structures, such as syntax and semantics (Duke & Cartwright, 2021; Hoover & Gough, 1990). If students' word recognition and language comprehension skills are poor, constraints will also exist on one's reading comprehension skills (Gough & Tunmer, 1986; Hoover & Gough, 1990).

Although the Simple View of Reading has substantial empirical validation and has been used in several studies examining readers' word recognition and language comprehension (for a meta-analysis, see García & Cain, 2014), it still is a very simplified view of reading comprehension, missing various bridging aspects and processes (Duke & Cartwright, 2021). For instance, word recognition and comprehension have also been considered to be interconnected via reading fluency (Duke & Cartwright, 2021; LaBerge & Samuels, 1974), which is the ability to read text accurately and rapidly (National Reading Panel, National Institute of Child Health & Human Development, 2000). This interconnection of automatized decoding, word recognition, and comprehension skills has also been supported by multiple empirical findings concerning learners' reading skills and reading fluency (for meta-analyses, see Lee & Yoon, 2017; Therrien, 2004). The development of decoding, word recognition, and reading fluency skills reduces the number of attentional resources allocated for these lower-level literacy skills and, further, improves reading comprehension (Fuchs et al., 2001; Tilstra et al., 2009). If the learners' lower-level literacy skills are not sufficient, the problems may affect higher-level comprehension processes (Hulme et al., 2015; Lervåg et al., 2018; Perfetti & Stafura, 2014). Thus, being literate in web-based reading environments also means that learners are able to combine and interrelate word meanings of the text (Duke & Cartwright, 2021; Perfetti & Stafura, 2014).

The next theoretical layer is based on the Construction-Integration Model (Kintsch, 1998), which means that readers need to move beyond word recognition and language comprehension in order to comprehend hierarchical representations of information within a text (i.e., to construct a textbase model).

Learners also need to construct a situational model—i.e., a deeper, coherent understanding of the text—by elaborating and integrating the textbase information with their knowledge base (Kintsch 1998). This means that learners also need to integrate information with their prior topic knowledge (Kintsch, 1998; Tarchi, 2010) and other content knowledge (Duke & Cartwright, 2021). However, while the Construction-Integration Model is developed for reading a single text (Kintsch, 1998), on the Internet, learners often read information from multiple online texts. Thus, the Multiple Documents Framework (Perfetti et al., 1999) also needs to be highlighted. Tasks that involve reading for learning from multiple texts require readers to construct the textbase and situation model of each text and to integrate these multiple situations into a document model (Perfetti et al., 1999; Strømsø, 2017). Many varied models of this framework exist, but most of them emphasize the importance of the document model, especially when the information is discrepant (Strømsø, 2017).

On the Internet, readers often gather information from multiple different online texts that vary in quality and credibility. On top of this, readers are often required to use online tools, such as search engines and instant messaging tools, while reading, and comprehension may frequently break down due to distractors, such as advertisements and pop-up windows. Hence, moving beyond theories such as the Simple View of Reading, the Construction-Integration Model, and the Multiple Documents Framework is necessary. Thus, the next theoretical layer is built on the Online Research and Comprehension Framework (Leu et al., 2004; Leu et al., 2019). In this framework, reading in web-based environments is defined as online research and comprehension—i.e., a self-directed, cyclical process in which learners construct texts and knowledge by employing the following component skills: (1) identifying task-relevant questions, (2) locating information, (3) evaluating information, (4) synthesizing information, and (5) communicating information (Kinzer & Leu, 2017; Leu et al. 2015; Leu et al., 2019).

The first component skill, *identifying task-relevant questions*, directs learners' reading process and knowledge construction (Leu et al., 2019; Owens et al., 2002). The task-relevant questions can be developed by learners themselves as an independent inquiry. However, in a school context, questions on a particular topic can also be given as a directed inquiry by a teacher or generated together by a teacher and students (Kingsley & Tancock, 2014).

After building an understanding of the given task, the second component skill, *locating information*, is needed. When locating information, learners type adequate search queries into a search engine and select relevant web pages from a results page (Cho & Afflerbach, 2015; Coiro & Dobler, 2007; Guinee et al., 2003; Rouet et al., 2011). Eye-tracking research has revealed learners' behaviors when using search engines to locate relevant information (for a review, see Lewandowski & Kammerer, 2020). For instance, although some elementary school students may predominantly base their text selection only on the titles, others are already paying attention to titles, snippet texts, and even URLs of their search results (Hautala et al., 2018). Successful online readers may also use more

time to formulate their search queries when task demands increase (Walhout et al., 2017).

Beyond the assessment of the search results, the third component skill, *evaluating information*, emphasizes that learners should also ensure the credibility and reliability of information (Flanagin & Metzger, 2008; Leu et al., 2019). Namely, a large amount of information on the Internet appears to be questionable, such as that published in suspicious media or under commercial interests (Britt & Gabrys, 2002; Pérez et al. 2018). In terms of the credibility of information, skilled learners evaluate different content- and source-based features, such as the relevance and accuracy of the content, author expertise and intentions, and information type and date (Braasch et al., 2012; Macedo-Rouet et al., 2019; Stadtler & Bromme, 2014). However, many middle and secondary school students tend to rely on content features, such as readability and topical relevance, in their evaluations (Coiro et al., 2015; Macedo-Rouet et al., 2019). Moreover, adolescent readers may be able to name the authors behind the information (Coiro et al., 2015; Macedo-Rouet et al., 2013), but they do not necessarily spontaneously evaluate the authors' competence or experience (Macedo-Rouet et al., 2019). Questioning the credibility of information seems to be challenging for readers, particularly when the information is biased (Kiili et al., 2018b; Pérez et al., 2018). Regarding this, a recent study by Kiili and colleagues (2018a) suggested, based on empirical validation of the original Online Research and Comprehension Framework, that in early adolescence, evaluation of the credibility of information can be divided into two component skills: confirming the credibility of information in more credible texts and questioning the credibility of information in less credible texts.

In addition, Kiili and colleagues (2018a) found that among elementary school students a fourth component skill, *synthesizing information*, was divided into two separate components. When learners are expected to synthesize main ideas from multiple online texts (for reviews, see Barzilai et al., 2018; Primor & Katzir, 2018), they are first required to identify main ideas from separate single online texts (Kiili et al., 2018a). After building coherence within a single online text, learners are required to build coherent intertextual relationships across multiple online texts (Cho & Afflerbach, 2017). Thus, comparing and contrasting different viewpoints from multiple online texts is also essential for successful synthesis (Cho & Afflerbach, 2015; Rouet, 2006). However, both elementary school (Kiili et al., 2020) and secondary school students (van Strien et al., 2014) may still base their knowledge construction on only one online text or fail to fully integrate the contents of different online texts. Moreover, it seems that younger readers rarely use their credibility evaluations when synthesizing information on the Internet (Hämäläinen et al., 2020).

Finally, the fifth component skill, *communicating information*, highlights that learners should also be able to communicate and interact with each other by sharing their learning outcomes (Leu et al., 2019). In the school context, learning outcomes may be shared, for example, through essays (Goldman et al., 2012) or by using different kinds of communication software, such as social networking

sites, chats, and emails (Kiili et al., 2018a; Leu et al., 2015). Specific instructions and prompts may help learners in information integration (Barzilai et al., 2018), but when the online information is controversial, learners also need practice in presenting well-justified arguments (Driver et al., 2000). Thus, being literate in the 21st century also means learners to be able to show awareness of an audience, such as by addressing their communication to the needs of the audience and using correct language (Lapp et al., 2011).

Previous research has shown some evidence of learners' literacy skills in relation to their performance in web-based reading environments. For instance, Rouet et al. (2011, experiment 2) found that elementary and middle school students' reading fluency was associated with their web page selection on a simulated search engine result page. Further, Macedo-Rouet et al. (2013, experiment 1) found that elementary school students' word recognition skills were associated with how well students justified their information source selection, which seems to be a prerequisite for successful evaluation of information. Maceco-Rouet et al. (2020) also found a relationship between adolescents' word recognition skills and link selection skills. However, the role of lower-level literacy skills seems to diminish with reading comprehension. For example, Salmerón et al. (2018) noticed that a word recognition task was associated with students' search selections on a search engine result page, but not with their actual navigation processes and reading of online texts. Further, Hahnel et al. (2018) found that students' performance in a word recognition task did not have a unique predictive power over their reading comprehension skills in evaluation of online information. Regardless of the grade level, previous research has emphasized reading comprehension when predicting learners' online research and comprehension performance (Coiro, 2011; Salmerón et al., 2018), but has been limited in regard to the role of reading fluency and written spelling.

On the Internet, the role of reading habits and reasoning skills may also increase when learners need to answer comprehension questions that, for example, require problem-solving. Digital reading habits (Naumann, 2015), such as reading online news and webpages, seem to be associated with learners' navigation behavior, but these individual differences need to be examined across learners' performance in online research and comprehension. Further, the role of inferential processes (Duke & Cartwright, 2021; Kendeou et al., 2016) and nonverbal reasoning (Adlof et al., 2010; Swart et al., 2017) may be important when learners are required to form effective search terms and to combine and contrast information when synthesizing their reading. However, previous research on online research and comprehension seems to miss nonverbal reasoning ability, even though reasoning skills may play a crucial role in complex, web-based reading environments. Prior topic knowledge may also play an important role, as actively reading students seem to develop not only stronger reading fluency and comprehension skills but also a larger knowledge base than students who read less (for reviews, see Mol & Bus, 2011; Schiefele et al., 2012). However, prior topic knowledge needs to be examined across learners' online research and

comprehension performance, as it has mainly been associated with their navigation behavior (Amadieu et al., 2009; Salmerón et al., 2005), and critical evaluation of information (Forzani, 2016). Thus, the first overarching goal of this dissertation is to increase our understanding of the extent to which learners' literacy skills (reading fluency, written spelling, and reading comprehension), reading habits, nonverbal reasoning ability, and prior topic knowledge were associated with their online research and comprehension performance.

1.2 Learners with reading difficulties and/or difficulties with attention and executive function in web-based reading environments

It is estimated that 5–15% of school-age children struggle with learning-related difficulties, and the two most common areas hampering learning are difficulties in reading and difficulties in attention and executive function (American Psychiatric Association, 2018). First, reading difficulties are characterized by the failure in accurate and fluent decoding and word recognition skills (Gough & Tunmer, 1986; Kirby et al., 2010; Lyon et al., 2003; Vellutino et al., 2004)—i.e., reduced reading fluency (Fuchs et al., 2001; LaBerge & Samuels, 1974; Perfetti & Stafura, 2014). Insufficient decoding, word recognition, and reading fluency skills seem to influence learners' higher-level comprehension processes (Hulme et al., 2015; LaBerge & Samuels, 1974; Perfetti & Stafura, 2014). Second, difficulties in students' attentional processes and executive function are characterized by the failure to focus, sustain, and shift attention (Mirsky et al., 1999), as well as by the failure to inhibit, for example, external distractions and update working memory contents (Friedman & Miyake, 2017; Miyake et al., 2000). Further, at a higher level of executive function, these difficulties are characterized by being unable to plan and monitor one's actions (for reviews, see Diamond, 2013; Friedman & Miyake, 2017), and thus, these kinds of difficulties may interfere with learners' reading comprehension by impeding their ability to build mental representations (for reviews, see Butterfuss & Kendeou, 2018; Follmer, 2018).

Difficulties in reading and attention and executive function also frequently show comorbidity among the same individuals (e.g., Moll et al., 2020; Willcutt et al., 2007; Willcutt & Pennington, 2000). Previous research has shown that difficulties in attention and executive function overlap and co-occur in 15–40% of the cases of learners with reading difficulties (Shaywitz et al., 1995; Willcutt & Pennington 2000; Willcutt et al., 2005). Learners with comorbid difficulties often face more academic difficulties than learners with either deficiency alone (e.g., Willcutt et al., 2007). Learners with reading difficulties and difficulties with attention and executive function may face even more difficulties online, as web-based reading environments may set additional requirements for learners in monitoring and regulating their actions (Cho et al., 2017; Coiro & Dobler, 2007).

Despite the prevalence of these difficulties, previous studies focusing on the component skills of online research and comprehension have mainly neglected readers with difficulties related to their learning. Only a few small case studies have examined online research and comprehension among learners with reading difficulties (Andresen et al., 2019a; Andresen et al., 2019b; Castek et al., 2011; Henry et al., 2012). For instance, Castek et al. (2011) and Henry et al. (2012) found that web-based reading environments can provide comprehension support for learners with reading difficulties by providing nontextual elements, such as pictures and videos, making them less dependent on their reading skills. Andresen et al. (2019a), however, showed that students with reading difficulties seemed not to use these kinds of non-textual elements more often than students without reading difficulties. Along with technological and visual elements, we know very little about how students with learning-related difficulties actually locate, evaluate, synthesize, and communicate information.

In web-based reading environments, students are also required to go beyond processing a single linear text and shift their attention between multiple online texts. This means that readers are required to integrate information and formulate conclusions across online texts (Dinsmore & Alexander, 2016; List & Alexander, 2017). Caccia et al. (2019), for instance, found that both students' self-reported and measured concentration difficulties were associated with their online research and comprehension performance in a web-based environment. It seems highly likely that reading in complex web-based environments is cognitively overloading. Especially for learners with comorbid difficulties, reading to learn in these kinds of reading environments may require a great deal of time, effort, and instructional support. Nevertheless, no previous studies have simultaneously examined reading difficulties and difficulties in attention and executive function in relation to learning from online information. Hence, the second overarching goal of this dissertation is to examine learners with reading difficulties and/or difficulties with attention and executive function to better understand those who may be ill-equipped in web-based reading environments.

1.3 Gender differences when reading in web-based reading environments

The gender effect has been a target of interest in literacy research as well as in research exploring learning-related difficulties. In literacy research, girls' advantages in both lower- and higher-level literacy skills have been shown in several studies (for reviews, see Logan & Johnston, 2010; Roivainen, 2011; see also, e.g., Quinn & Wagner, 2015; Torppa et al., 2018). The gender effect has also been discovered in large-scale international studies, such as the PIRLS (Progress in International Reading Literacy Study; Mullis et al., 2017) and PISA (Programme for International Student Assessment; OECD, 2019), although these differences vary between different countries. For example, the gender gap was

twice as wide in Finland as in Italy or France (OECD, 2019). In research exploring learning-related difficulties, gender differences seem to exist in the identification of reading difficulties (Quinn, 2018; Wheldall, & Limbrick, 2010) as well as in the identification of difficulties in attention and executive function (Owens et al., 2015). It seems that more boys than girls have reading difficulties and that boys with reading difficulties are more frequently identified than girls with similar difficulties (Quin, 2018; Wheldall, & Limbrick, 2010). Further, boys often receive higher ratings for hyperactivity, impulsivity, and inattention than girls (for a review, see Gershon, 2002), although these differences seem mainly to concern hyperactivity and impulsivity (Owens et al., 2015). It has also 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).

When learners read in web-based reading environments, it seems that a similar pattern regarding the gender effect exists. Girls seem to have an advantage in web-based reading environments when compared to boys (Forzani, 2016; Naumann & Sälzer, 2017; Salmerón et al., 2018). Girls also seem to navigate better—i.e., tend to visit and re-visit task-relevant web pages more frequently—than boys (OECD, 2011). However, not all studies have identified such a relation between learners' gender and online text reading scores; some have even found that boys outperformed girls when reading to learn from online graphs (Caccia et al., 2019). Thus, more research is needed concerning the gender effect in web-based reading environments. In particular, no previous studies have seemed to evaluate the gender effect in association with learners' online research and comprehension performance, including individuals with difficulties in reading as well as in attention and executive function. Hence, the third overarching goal of this dissertation is to evaluate the gender effect in association with learners' online research and performance and whether, for example, boys with higher ratings of attention and executive function difficulties also face more difficulties when reading to learn from online information than girls with similar kinds of difficulties. Based on the three aforementioned goals based on this theoretical background, I next present the three main aims of this dissertation, together with the research questions and hypotheses.

1.4 Research aims, questions, and hypotheses

The main objective of this dissertation was to shed light on sixth-grade students' online research and comprehension performance. Three original studies were carried out to address the following research aims and questions. These aims and questions, including the set hypotheses, are not identical to the ones presented in the original studies but are combined into a coherent whole to make the comparison of the studies easier for a reader.

1) To increase our knowledge of the extent to which learners' literacy skills (reading fluency, written spelling, and reading comprehension), reading

habits, nonverbal reasoning ability, and prior topic knowledge were associated with their online research and comprehension performance (Study I, Study III).

> RQ1: How are learners' literacy skills (reading fluency, written spelling, and reading comprehension), reading habits, nonverbal reasoning ability, and prior topic knowledge associated with their online research and comprehension performance?
>
> H1: Reading comprehension, reading habits, nonverbal reasoning ability, and prior topic knowledge were expected to independently contribute to explaining the variance of learners' online research and comprehension performance. Due to a limited amount of previous research, no hypothesis was set on whether reading fluency and written spelling would affect learners' online research and comprehension performance through reading comprehension or whether these skills would contribute independently.

2) To examine interindividual differences in students' online research and comprehension performance among learners with reading difficulties and/or difficulties in attention and executive function (Study II, Study III).

> RQ2: How are learners' difficulties in reading and/or in attention and executive function associated with their online research and comprehension performance?
>
> H2: Learners' difficulties in reading and/or in attention and executive function were expected to contribute independently to explaining the variance of learners' online research and comprehension performance.

3) To evaluate the gender effect in association with learners' online research and comprehension performance, including students with learning-related difficulties (Study I, Study II).

> RQ3: How is gender associated with learners' online research and comprehension performance?
>
> H3: Gender was expected to contribute independently to explaining the variance of learners' online research and comprehension performance, also among students with learning-related difficulties. On average, girls were expected to outperform boys in online research and comprehension.

2 METHODS

2.1 Participants and procedure

Participants in Studies I–III took part in an Academy of Finland-funded project (PI Paavo H.T. Leppänen) called *Internet and learning difficulties: Multidisciplinary approach for understanding information seeking in a new media (eSeek,* 2014–2017*)* that aimed at reaching a better understanding of new reading demands on the Internet for school-aged children. In Studies I and II, the participants were 426 sixth graders (207 girls, 219 boys) aged 12 to 13 years (*M* age = 12.34, *SD* = 0.32). They were recruited by contacting (via email or phone) principals representing eight Finnish elementary schools. The principals forwarded the informed recruitment request to classroom teachers (24 classes), who then forwarded the request to the students' guardians.

In Study III, 13 of the 426 participants were excluded from the analysis because of missing data essential for assigning students to learner groups. As I was especially interested in how learners with reading difficulties and/or difficulties in attention and executive function performed online, an additional 23 students with these identified difficulties were recruited. I contacted special education teachers and psychologists, who then forwarded the informed recruitment request to guardians. Thus, the Study III participants were 436 sixth-grade students (206 girls, 230 boys; *M* age = 12.34, *SD* = 0.33), including those with difficulties in reading and/or attention and executive function.

Data collection was conducted during the years 2014–2016 from both large and average-sized schools from urban and rural areas. A statement from the Ethical Committee of the University of Jyväskylä was obtained, and the students participated voluntarily with the written consent of their guardians. Most of the guardians had at least an upper secondary education (93% of females, 88% of males). This is close to the Finnish national average, which is 88.3% of people

aged 25–54 with at least an upper secondary education level (Eurostat, 2013). The participating students were taught in mainstream classrooms following the Finnish National Curriculum (Finnish National Board of Education, 2004).

Trained research staff collected the data in three group-administered test sessions, each 45 minutes long, and one 5-minute individual test session. The group-administered sessions were conducted in the classrooms during regular school hours. During the first two group sessions, students completed the paper–pencil tests (reading fluency, written spelling, reading comprehension, and nonverbal reasoning) and filled in a questionnaire concerning their reading habits. In the third group session, the students completed a web-based online research and comprehension assessment on laptops after answering prior topic knowledge questions. If needed, students were allowed to use their 15-minute break between classes to complete the task, and the researchers provided technical assistance with the test application when needed. The students' performance was recorded with a screen capture program and saved as log files. In the individually administered test session, students completed the pseudoword reading test (see below) in a quiet location at school.

2.2 Ethical considerations

All the research procedures used in this dissertation followed the ethical guidelines of the Finnish National Board on Research Integrity (Finnish National Board on Research Integrity, 2009). All the students participated voluntarily, and their guardians signed a written consent form for their children's participation. This consent form included an information letter concerning the aim of the research, nature, and use of the collected data, voluntariness of the participation, and the researchers' contact information for further questions. Moreover, students and guardians were informed of the possibility of withdrawing from the study at any time without negative consequences. Guardians and teachers were also given some feedback about the children's online research and comprehension performance, and ideas how to support these young learners to become better Internet readers. In the data analyses, students' privacy and confidentiality issues were taken into account by using only pseudonymized data and storing the data in secured servers of the University of Jyväskylä. Data analyses and reporting of results were conducted with great accuracy.

2.3 Measures

2.3.1 Online research and comprehension, including prior topic knowledge

Students' online reading skills were measured with a Finnish version of an online research and comprehension assessment (Internet Lukemisen Arviointi [ILA];

Kiili et al., 2018b). The Finnish version was modified from the original version developed in the United States with good levels of validity and reliability (Online Research and Comprehension Assessment [ORCA]); Leu et al., 2015). Both versions of the web-based assessment simulate Internet environment and follow the evidence-centered design approach (Goldman et al., 2012; Mislevy et al., 2003). In this approach, assessments are based on a domain model of relevant theories and empirical findings of interest (Goldman et al., 2012; Mislevy et al., 2003). Both assessments are based on the Online Research and Comprehension Framework (Leu et al., 2004; Leu et al., 2019).

In Studies I–III, the online research and comprehension assessment measured four component skills: (1) locating information, (2) evaluating information, (3) synthesizing information, and (4) communicating information. Next, the domain model is followed by the conduction of student and task models (Goldman et al., 2012; Mislevy et al., 2003). The student model presents claims and constructs regarding students' performance, and the task model presents tasks in which students engage in an assessment. However, contrary to the domain model of online research and comprehension, neither the ORCA nor the Finnish version of the assessment included a task measuring the component of identifying important questions. Instead, the assessment began with an email containing a common task assignment. A fictitious school principal instructed students to explore the health effects of energy drinks by examining four different online texts (two on news pages [T1, T4], one on an academic web page [T2], and one on a commercial web page [T3]) and to form a justified recommendation on whether an energy drink vending machine should be purchased for the school. Two avatar students prompted participants via a social networking site and a chat message window in a closed, web-based task environment.

In *locating information*, students formulate a relevant search query by using relevant search terms as efficiently as possible. Transition from this student model was done by instructing participants to locate two web pages (T2, T4) with a search engine. In this task model of locating, the avatar gave students the following instructions: "My friend gave me a tip about a web page of a certain university presenting information related to energy drinks. Please find this web page [T2]"; "I have heard my friends talking about the health effects of energy drinks on teeth. Next, please find a web page informing these effects [T4]". After the search query, students received the search engine result page and were asked to distinguish the relevant page from the irrelevant ones. Both the formulation of search queries and the time spent on both locating tasks was scored. The Kappa values for inter-rater reliability were 1.00 for locating, showing successful ascertaining of the evidence from students' task products. However, the observed variable of the first search query (T2) did not load on the locating factor and thus was omitted from the analyses in the validation of the assessment (Kiili et al., 2018b).

In *evaluating information*, students evaluate the authors' expertise and credibility of information. Moving beyond this student model was achieved by

instructing participants to evaluate two web pages (T2, T3). In the task model of evaluation, the avatar asked three questions in the chat message window: (1) "Who is the author of the web page?"; (2) "Is the author expert on health issues related to energy drinks? Why do you think so?"; and (3) "Is the information provided on the web page reliable? Why do you think so?" Both the evaluation of the authors' expertise and the credibility of information were scored. The Kappa values (ranging from .95 to .98) for interrater reliability showed successful ascertaining of the evidence from students' evaluation task products. Further, the statistical model validating the factor structure suggested that the evaluation component was divided into two sub-components: (2a) confirming the credibility of information in more credible texts and (2b) questioning the credibility of information in less credible texts (Kiili et al., 2018).

In *synthesizing information*, students identify the main ideas from various online texts and integrate information coherently by using connectives. Moving beyond this student model was achieved by instructing participants to collect main ideas from all four online texts with a note-taking tool. After this, students synthesized what they had learned about the health effects of energy drinks across the texts by writing a summary based on their notes on the social networking site. Both the identification of the main ideas from single texts and the actual synthesis were scored. The Kappa values (ranging from .78 to 1.00) for interrater reliability showed successful ascertaining of the evidence from students' synthesizing task products. Further, the statistical model validating the factor structure suggested that the synthesizing component was divided into two sub-components: (3a) identifying main ideas from a single online text and (3b) synthesizing information across multiple online texts (Kiili et al., 2018b).

In *communicating information*, students give supporting arguments to their stance, are aware of their audience, and use clear, polite language. This student model was turned to the task model by students responding to the principal's email with a justified recommendation concerning the purchase of the energy drink vending machine. The quality of both argumentation and communication practices were scored. The Kappa values (ranging from .72 to .94) for interrater reliability showed successful ascertaining of the evidence from students' communication task products and formed one factor of communicating information.

More detailed information on the stimulus materials, scoring criteria, and descriptive statistics is presented in the original articles. Of note is that if a student failed in the locating tasks, the avatar provided a link to the correct online text. Thus, students were still able to read the correct online texts and receive credit in the next parts of the assessment. The McDonald's omega reliability coefficient for the total score for online research and comprehension was .88. Finally, *prior topic knowledge* in relation to the topic of the online research and comprehension assessment was measured, but because of the relatively poor reliability (the McDonald's omega reliability coefficient .31) and insignificance of this variable, it was excluded from the analyses after Study I.

2.3.2 Literacy skills and reading habits

Reading fluency was assessed with three tests: (1) a time-limited word recognition test (Reading Test for Primary School [ALLU]; Lindeman, 1998), (2) a time-limited word chain test (Dyslexia Screening Test for Youth and Adults; Holopainen et al., 2004), and (3) an oral pseudoword reading test (Jyväskylä Longitudinal Study of Dyslexia [JLD]; Eklund et al., 2015). The first two were administered in groups, and the last was administered individually. In the time-limited word recognition test of 80 items, the score was the number of correctly connected picture–word pairs within two minutes (a picture and four alternative words per item). In the time-limited word chain test of 25 items, the score was the number of correctly separated words within 90 seconds (four words per an item/chain). In the oral pseudoword reading test of 38 items, the score was the number of correctly read pseudowords divided by the time spent on reading (a short text of 38 pseudowords, a total of 277 letters). Based on these tests, a reading fluency factor was formed, and the McDonald's omega reliability coefficient was .79.

Written spelling was assessed with a group-administered test that consisted of writing 12 four-syllable pseudowords from dictation (Jyväskylä Longitudinal Study of Dyslexia [JLD]; Eklund et al., 2015). The score was the number of correctly spelled items. The McDonald's omega reliability coefficient was .50. It seems that the somewhat low omega value was due to the omega's assumption of unidimensionality (see, e.g., Savalei et al., 2019). Thus, the written spelling variable was also excluded from the analyses after Study I.

Reading comprehension was assessed using a group-administered subtest of the standardized Finnish reading test battery (Reading Test for Primary School [ALLU]; Lindeman, 1998). In this subtest of a two-page (557 words) expository text of instructions for consumers, and 12 (four-option) multiple choice questions, the score was one point for each item correctly responded to. The 12 items represented the following categories: (a) detail or fact (q12), (b) cause-effect or structure (q3), (c) conclusion or interpretation (q2, q7, q9, q10), (d) concept or phrase (q4, q5, q6), and (e) main idea or purpose (q1, q8, q11). The McDonald's omega reliability coefficient was .64. As this subtest includes five different types of items that were unevenly represented, it seems that the omega's assumption related to unidimensionality does not hold perfectly (see, e.g., Savalei et al., 2019). However, previous research has shown that the subtests of the ALLU test battery can also be used separately with a good level of validity (Soodla et al., 2019; Torppa et al., 2020).

Reading habits were assessed using a self-report questionnaire of eight items. The first four items measured print reading frequency: frequency of reading (a) books, (b) newspapers, (c) magazines, and (d) comics. The last four items measured digital reading frequency: frequency of reading (a) ebooks, (b) online newspapers, (c) websites on different topics, (d) blog postings, and (e) forum posts. Ratings were given on a 5-point Likert scale [1 = hardly ever, 2 = rarely (1–2 times per month), 3 = 1–2 times per week, 4 = almost every day, 5 = every day]. The McDonald's omega reliability coefficient was .62. Based on the omega value,

the assumption of unidimensionality does not seem to hold completely (Savalei et al., 2019). It seems that students prefer different kinds of media (see also Jang et al., 2021); thus, reading habit variables were used at the item level.

2.3.3 Attention and executive function difficulties and nonverbal reasoning ability

Attention and executive function difficulties were assessed with the validated Attention and Executive Function Rating Inventory (ATTEX; Klenberg et al., 2010b). In this inventory of 55 items, students' difficulties in attention and executive function were rated in school-related situations by their teachers (N = 24). The 55 items belonged to ten scales (e.g., distractibility, impulsivity, sustaining attention, and execution of action), and each item had a three-point response scale (0 = not a problem; 1 = sometimes a problem; 2 = often a problem). The ATTEX inventory is available in English as an appendix in Klenberg et al., (2010b). The McDonald's omega reliability coefficient was .94.

Nonverbal reasoning ability was assessed with the group-administered Raven's Standard Progressive Matrices (RSPM; Raven, 1998). The shortened test version consisted of 30 visuospatial task items (every second item from the full version). The score was the number of items correctly responded to. The McDonald's omega reliability coefficient was .76.

2.3.4 Students' learner groups

Learners with reading difficulties were assigned to Group 1 based on their reading fluency factor score below the 10th percentile (n = 39; 33% females). The 10th percentile cut-off value was formed based on the original group of 426 participants. The factor scores for the 23 supplementary students were calculated by adding one student at a time to the main data, and then running the factor analysis to get the factor score for each of these students. This was done to prevent overrepresentation of this supplementary sample in the factor score estimation. The lowest 10th percentile on a reading composite score (e.g., accuracy and fluency measures), is often considered as a cut-off point for dyslexia (Eklund et al., 2015; Snowling & Melby-Lervåg, 2016; Torppa et al., 2010). *Learners with attention and executive function difficulties* were assigned to Group 2 according to the teacher-rated difficulties in attention and executive function. Based on the ATTEX manual (Klenberg et al., 2010a), boys with scores ≥ 36 and girls with scores ≥ 20 belonged to the group of students with attention and executive function difficulties (n = 37; 19% females). The ATTEX seems to be sensitive in identifying children with attention deficit disorders, when applying different cutoff scores for boys and girls (Klenberg et al., 2010b). *Learners with comorbid difficulties* were assigned to Group 3 based on their difficulties in both areas (n = 17; 24% females). The remaining students were assigned to Group 4: *learners without identified difficulties* (n = 343; 53% females).

2.4 Data analyses

The quantitative data analyses used in Studies I–III are summarized in Table 1. Studies I and II used a quantitative, variable-centered research approach, and Study III was based on a quantitative, person-centered research approach. In all three studies, the research design was cross-sectional. Descriptive statistics and reliability analyses were performed with IBM SPSS Statistics (versions 22–26), and the more sophisticated analyses, such as structural equation modeling and latent profiling, were conducted with the Mplus software (versions 7.3–8.0; Muthén & Muthén, 1998–2017). Since the pre-analyses of the data revealed some non-normality in the distributions of the observed variables, either the maximum likelihood robust (MLR) estimator or the weighted least square mean and variance adjusted (WLSMV) estimator were used in the analyses (Muthén & Muthén, 1998–2017).

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). Missing values (0%–12%, depending on the variable) were due, for example, to sickness absences. Model parameters were estimated using all incomplete cases.

In Study I, confirmatory factor analysis (15 observed online research and comprehension variables) was used in the preliminary phase analyses. The comparison of nested measurement models of online research and comprehension component skills was implemented using a DIFFTEST option (to obtain a correct chi-square difference test when the WLSMV estimator is used). Next, the following variables were also included in the structural equation model: reading fluency as a latent factor (see 2.2.2 Literacy skills and reading habits); written spelling, reading comprehension, nonverbal reasoning, and prior topic knowledge as observed variables; and gender. These predictor variables were evaluated both in relation to a common online research and comprehension factor as well as in relation to the six first-order factors of online research and comprehension component skills revealed in the nested model comparisons.

In Study II, a multigroup confirmatory factor analysis was used in the preliminary phase analyses. These analyses were carried out to test factorial invariance of teacher-rated attention and executive function difficulties (ATTEX; Klenberg et al., 2010b) across the gender groups. The factorial invariance comparisons were conducted on four levels: (1) configural invariance, (2) weak factorial invariance, (3) strong factorial invariance, and (4) strict factorial invariance (Meredith, 1993). After these comparisons, the factor scores were saved. Next, the 12 items of the paper–pencil reading comprehension task were included in a confirmatory factor analysis. The first structural equation model was formed by setting the saved factor scores for girls' and boys' difficulties in attention and executive function together with the confirmatory factor analysis

of the reading comprehension items. Gender, reading fluency, and nonverbal reasoning were controlled. The second structural equation model was constructed by again using the saved attention and executive function difficulty factor scores, but now with the same online research and comprehension measurement model used in Study I. Gender, reading fluency, nonverbal reasoning, and now also reading comprehension were controlled.

In Study III, the factor scores of the six online research and comprehension component skills were saved, standardized (M = 1, SD = 0), and, in addition, calculated one student at a time for the 23 students of the supplementary sample. This one-by-one calculation was done to prevent overrepresentation of this supplementary sample in the factor score estimation. Next, latent profile analysis was applied to identify the students' different online research and comprehension performance profiles. To examine students' online research and comprehension profiles against the learner groups and reading habits, auxiliary analyses were conducted using pairwise comparisons as well as DCAT (categorical variables) and BCH (continuous variables) options.

As students were nested within 24 different classrooms and eight schools, intra-class correlations were calculated for the online research and comprehension factors. The analysis showed that 0–1.1% of the variance was explained by the differences at the school level and 2.4–7.8% at the classroom level. For instance, the multilevel latent profile analysis was used to examine whether the probability that a student belonged to a specific online research and comprehension profile varied significantly across the classrooms. However, a statistically significantly larger probability that a student would belong to a certain profile in some classrooms than in other classrooms was not found (p-values >.05).

In Studies I and II, the following cutoff criteria were applied: $\chi 2$-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). In Study III, the following information criteria were used: Akaike information criteria (AIC), Bayesian information criteria (BIC), and sample-size-adjusted Bayesian information criteria (aBIC). In addition, the Vuong-Lo-Mendell-Rubin (VLMR) and the adjusted Lo-Mendell-Rubin (aLMR) likelihood ratio tests, as well as entropy values and the average latent class probabilities, were also considered. More detailed information on the methodology used in Studies I–III can be found in the original articles.

TABLE 1 Summary of the data analyses

	Study I	Study II	Study III
Aim of the study	To evaluate the extent to which students' literacy skills, nonverbal reasoning ability, prior topic knowledge, and gender associate with their online research and comprehension performance.	To investigate the associations of students' difficulties in attention and executive function with their reading comprehension, as well as their online research and comprehension performance. To investigate whether these associations were similar for both genders.	To examine inter-individual differences in students' online research and comprehension performance profiles among different learner groups. To examine students' print and digital reading habits in association with their online research and comprehension performance profiles.
Research approach	Quantitative Variable-centered	Quantitative Variable-centered	Quantitative Person-centered
Research Design	Cross-sectional	Cross-sectional	Cross-sectional
Participants	Individuals: sixth-grade students (N = 426)	Individuals: sixth-grade students (N = 426)	Individuals: sixth-grade students (N = 436) Groups: four learner groups based on students' identified difficulties in reading and/or attention and executive function
Data sources	Paper–pencil tests, Screen captures, Log files, Students' written responses on the ORCA	Teacher ratings, Paper–pencil tests, Screen captures, Log files, Students' written responses on the ORCA	Teacher ratings, Paper–pencil tests, Questionnaire about students' reading habits, Screen captures, Log files, Students' written responses on the ORCA

continues

TABLE 1 continues

	Study I	Study II	Study III
Variables	Independent variables: reading fluency, written spelling, reading comprehension, nonverbal reasoning, prior topic knowledge, gender Dependent variables: online research and comprehension, locating, confirming credibility, questioning credibility, identifying main ideas, synthesizing, communicating	Independent variables: teacher-rated attention and executive function difficulties Dependent variables: reading comprehension, online research and comprehension, locating, confirming credibility, questioning credibility, identifying main ideas, synthesizing, communicating Controlled variables: gender, reading fluency, nonverbal reasoning, reading comprehension	Independent variables: reading fluency, teacher-rated attention and executive function difficulties, learner groups, reading habits Dependent variables: locating, confirming credibility, questioning credibility, identifying main ideas, synthesizing, communicating
Statistical methods	Confirmatory factor analysis Nested model comparisons Structural equation modelling	Multigroup confirmatory factor analysis Factorial invariance comparisons Structural equation modelling	Confirmatory factor analysis Latent profile analysis Auxiliary analyses Pairwise comparisons

3 OVERVIEW OF THE ORIGINAL STUDIES

The original Studies I–III explored a multiple set of single variables and characteristics, such as literacy skills (reading fluency, written spelling, and reading comprehension), reading habits, nonverbal reasoning ability, and prior topic knowledge, as well as learning-related difficulties, in association with sixth-grade students' online research and comprehension performance. Study III also extended the examination by using a person-centered approach to identify students' online research and comprehension performance profiles among different learner groups. All three original studies substantially contributed to the literacy research in web-based reading environments, especially Study III, by including both learners with reading difficulties and learners with attention and executive function difficulties. In the following overview, the terminology used may differ to some extent from the terms used in the original studies. However, the use of consistent terminology across the overview enables me to make the comparison of the studies easier for a reader. Figure 1 summarizes the presented models in Studies I–III.

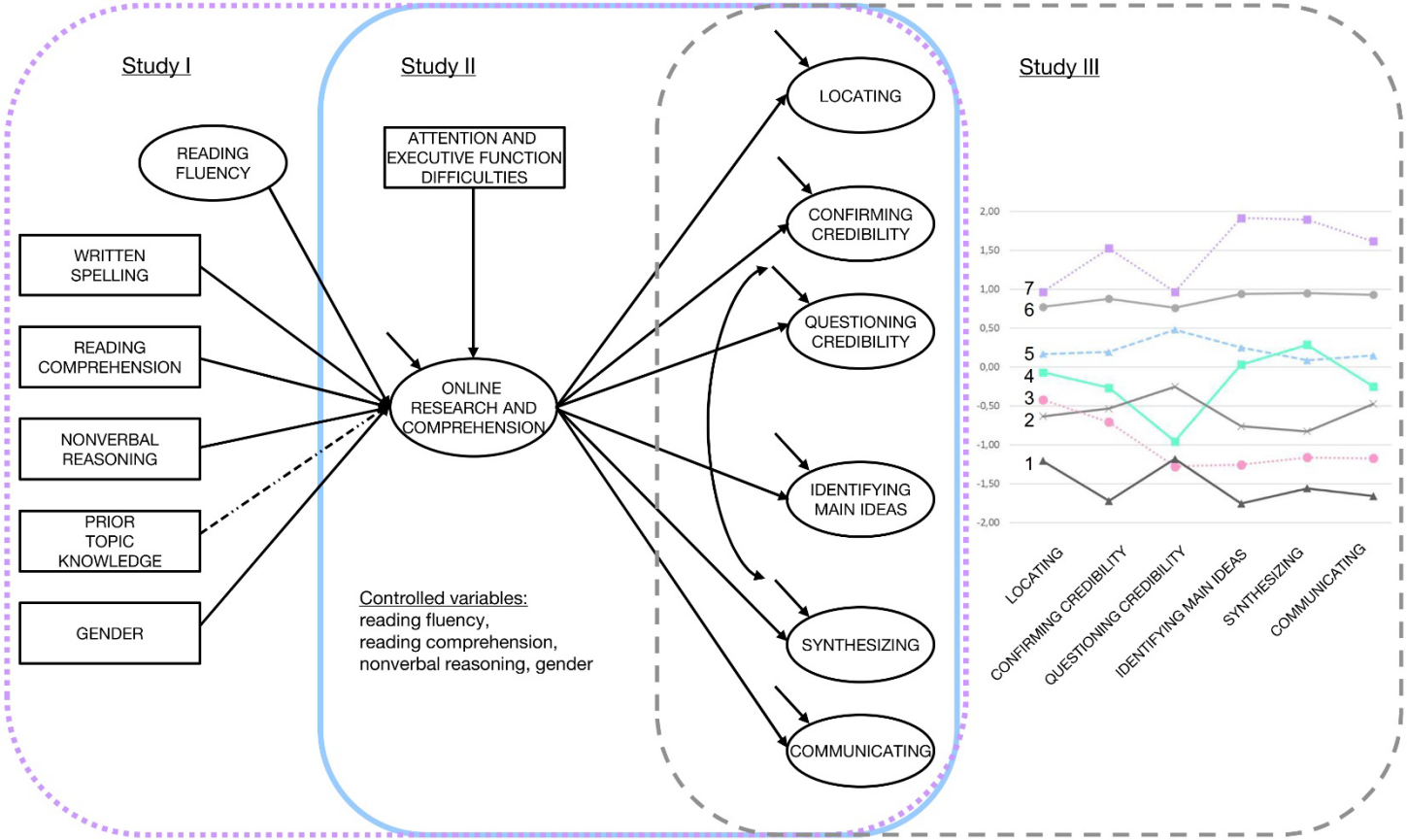

FIGURE 1 Summary of the statistical models presented in Studies I–III. Students' learner groups and reading habits were included in the analyses in Study III. (1) very poor performers, (2) poor performers, (3) below-average performers, (4) average performers with low questioning credibility scores, (5) average performers, (6) good performers, and (7) top performers.

3.1 Study I: Literacy skills and online research and comprehension: Struggling readers face difficulties online

Study I aimed to evaluate the extent to which literacy skills (reading fluency, written spelling, and reading comprehension), together with nonverbal reasoning, prior topic knowledge, and gender, were associated with sixth-grade students' online research and comprehension performance (RQ1, RQ3). It was hypothesized that reading comprehension, nonverbal reasoning, prior topic knowledge, and gender would independently contribute to explaining the variance of online research and comprehension performance (H1, H3). No hypothesis was set for the examination of whether reading fluency and written spelling would independently contribute to explain the variance of online research and comprehension or whether these skills would contribute through reading comprehension, as there was too little existing research investigating these lower-level literacy skills in relation to online research and comprehension.

Study I revealed that the sixth graders' (N = 426, 207 girls, 12–13 years) online research and comprehension skills examined with a validated web-based assessment were divided into six highly correlated factors (Figure 1). These factors formed a common factor of online research and comprehension. This common factor explained 26% of locating information with a search engine (λ = .51; p<.001), 42% of confirming the credibility of information in more credible texts (λ = .65; p<.001), 37% of questioning the credibility of information in less credible texts (λ = .61; p<.001), 71% of identifying main ideas from a single online text (λ = .84; p<.001), 63% of synthesizing information across multiple online texts (λ = .79; p<.001), and 63% of communicating a well-justified and source-based position (λ = .80; p<.001). The results also showed that the residuals of questioning credibility of information and synthesizing information had a negative correlation (r = -.33; p<.01), which means an inverse relation between the residuals.

Supporting the set hypothesis (H1, H3), the findings of the structural equation model showed that reading comprehension (β = .34, p<.01), nonverbal reasoning (β = .14, p<.001), and gender (β = .34, p<.001) independently contributed to explaining the variance of students' common online research and comprehension performance. Also, lower-level literacy skills—i.e., reading fluency (β = .18, p<.01) and written spelling (β = .17, p<.001)—both independently contributed to common online research and comprehension performance. Contrary to expectations, the relationship between students' prior topic knowledge and common online research and comprehension was nonsignificant. Altogether, these predictor variables explained 57% of the common online research and comprehension variance (Figure 1). The fit indices of the model indicate a good model fit.

Further, the findings of Study I also showed that reading comprehension was associated with all other online research and comprehension component skills except locating information. Written spelling was associated with locating,

synthesizing, and communicating, whereas reading fluency was only associated with communication. Furthermore, nonverbal reasoning was associated with identifying main ideas and communicating, whereas prior topic knowledge was not statistically significantly associated with any component skills. Finally, gender was associated with all other component skills except locating and confirming the credibility of information in more credible texts. This optional model also had a good model fit (see original Study I, Table 2).

Overall, the results of Study I indicated that reading comprehension, was the strongest predictor of students' online research and comprehension performance. This means that students with below-average reading comprehension scores were very likely to have difficulties in online research and comprehension. The linear relationship between lower-level literacy skills and online research and comprehension performance suggests that those with below average reading fluency and written spelling were also very likely to have difficulties in online research and comprehension. Additionally, students with difficulties in nonverbal reasoning ability struggled online. Deficiencies in literacy skills and nonverbal reasoning seem to affect students' ability to learn from online information (Figure 1). Further, also gender, predicted students' online research and comprehension performance. It means that, on average, girls outperformed boys (Figure 2).

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

Study II aimed to investigate the associations of teacher-rated difficulties in attention and executive function with sixth-grade students' reading comprehension, as well as online research and comprehension performance (RQ2). Study II also explored whether these associations were similar for girls and boys (RQ3). Two hypotheses were set. First, it was hypothesized that students' difficulties in attention and executive function were associated with their online research and comprehension performance (H2). Second, it was hypothesized that difficulties in attention and executive function would contribute less to girls' than boys' performance (H3).

As a preliminary step of analyses, Study II (N = 426, 207 girls, 12–13 years) showed that the factor structure of the teacher-rated attention and executive difficulties was similar for both genders, thereby forming one general factor of students' attention and executive function difficulties. Only some minor gender differences were observed in the factor loadings and the intercepts of the variables, such as motor hyperactivity and sustaining attention. Next, the preliminary step analyses also showed that the 12 items of the paper–pencil reading comprehension task formed a single general factor of reading comprehension.

After controlling for gender, reading fluency, and nonverbal reasoning, the structural equation models revealed that difficulties in attention and executive function played a role in students' online research and comprehension performance in the web-based task environment but had no associations left with students' reading comprehension performance in the paper-pencil task. In the model of online research and comprehension performance (Figure 1), students' reading comprehension skills in the paper-pencil task were also controlled. The fit indices of the models indicated a good model fit, and the findings supported the set hypothesis (H2).

The findings also showed that no interaction effect of gender was observed between students' difficulties in attention and executive function and their reading comprehension performance. An interaction effect of gender was found between students' difficulties in attention and executive function and their online research and comprehension performance. Contrary to the hypothesis (H3), difficulties in attention and executive function had a larger association with girls' online research and comprehension performance (9%, $p < .05$) than with that of boys (4%, $p < .01$).

Overall, the results of Study II indicated that students with difficulties in attention and executive function would struggle more in the complex, web-based online research and comprehension task than in the less complex paper–pencil reading comprehension task. Surprisingly, girls with difficulties in attention and executive function seemed to face more difficulties when reading to learn from online information than boys with similar kinds of difficulties (Figure 3). However, it remains for future studies to explore the possible reasons for the observed gender difference.

FIGURE 2 Online research and comprehension performance of all girls and boys.

FIGURE 3 Online research and comprehension performance of girls and boys with attention and executive function difficulties.

3.3 Study III: Online research and comprehension performance profiles among sixth-grade students, including those with reading difficulties and/or attention and executive function difficulties

Study III aimed to move beyond the effects of single variables and characteristics by examining interindividual differences in sixth-grade students' online research and comprehension performance profiles among different learner groups (RQ2). As an additional layer of examination, Study III also explored how students' reading habits were associated with their online research and comprehension performance profiles (RQ1). No hypotheses for the number or nature of the online research and comprehension performance profiles were set. Like other person-centered approaches, latent profile analysis is typically conducted in an exploratory manner (Hoijtink, 2001; Meyer & Morin, 2016). However, sixth graders' difficulties in reading and/or attention and executive function (H2) as well as their reading habits (H1) were expected to be associated with their online research and comprehension performance.

The results of Study III (N = 436, 206 girls, 12–13 years) revealed seven different online research and comprehension performance profiles: (1) very poor performers (7.6%), (2) poor performers (5.7%), (3) below-average performers (22.5%), (4) average performers with low questioning credibility scores (13.3%), (5) average performers (22.7%), (6) good performers (22.9%), and (7) top performers (5.3%). Based on the latent profile analysis, most of the profiles reflected students' online research and comprehension performance levels across the six component skills presented in Study I. However, there was one exception. Students belonging to the profile of the average performers with low questioning credibility scores were quite near the average in other areas but performed below average in questioning the credibility of information in less credible texts (Figure 1).

Supporting the set hypothesis (H2), the findings of the auxiliary analyses showed that all top performers were students without identified difficulties, and students with learning-related difficulties were more likely to belong to the lower performance profiles (Figure 4). Of the learners with reading difficulties, 59.0% belonged to the lowest three performance profiles. Of the learners with teacher-rated attention and executive function difficulties, 67.5% belonged to the lowest three performance profiles. Notably, the proportion of learners with attention and executive function difficulties (30.3%) in the lowest performance profile was higher than the proportion of learners with reading difficulties (12.1%). Of the learners with comorbid difficulties in reading as well as attention and executive function, 82.4% belonged to the lowest three performance profiles.

Interestingly, Study III and the person-centered approach, precisely latent profile analysis, also revealed that a couple of students with the aforementioned difficulties performed better than expected based on their deficiencies. Even though most of the students with difficulties in their reading fluency or attention

and executive function were more likely to belong to the lower performance profiles, 25.7% of learners with reading difficulties and 16.2% of learners with attention and executive function difficulties performed at average or good levels of online research and comprehension.

In regard to the other hypothesis (H1), frequency of reading longer and more vocabulary-rich texts, such as books, blog postings, and ebooks, was associated with students' online research and comprehension performance. Frequent reading of books had the strongest association with successful online research and comprehension performance. However, frequency of reading texts that were shorter in length and probably narrower in vocabulary, such as comics and online forum posts, had no statistically significant associations.

Overall, the results of Study III indicated that students who were very poor or poor performers struggled more or less with all component skills of online research and comprehension, whereas good and top performers were quite skilled or skilled in all areas (Figure 1). Questioning the credibility of the biased information seemed to be particularly challenging for some students. Of note is that some students with identified difficulties, however, may have used some compensatory strategies or mechanisms to overcome their challenges. Saying this, I suggest that reading longer and more vocabulary-rich texts, both print and digital, may be one compensatory mechanism that can increase students' knowledge base necessary when reading to learn from online information. Still, there were students without identified difficulties who clearly faced difficulties in their online research and comprehension performance (Figure 4). It remains for future studies to explore what kind of role that, for instance, motivational aspects play in students' online research and comprehension performance.

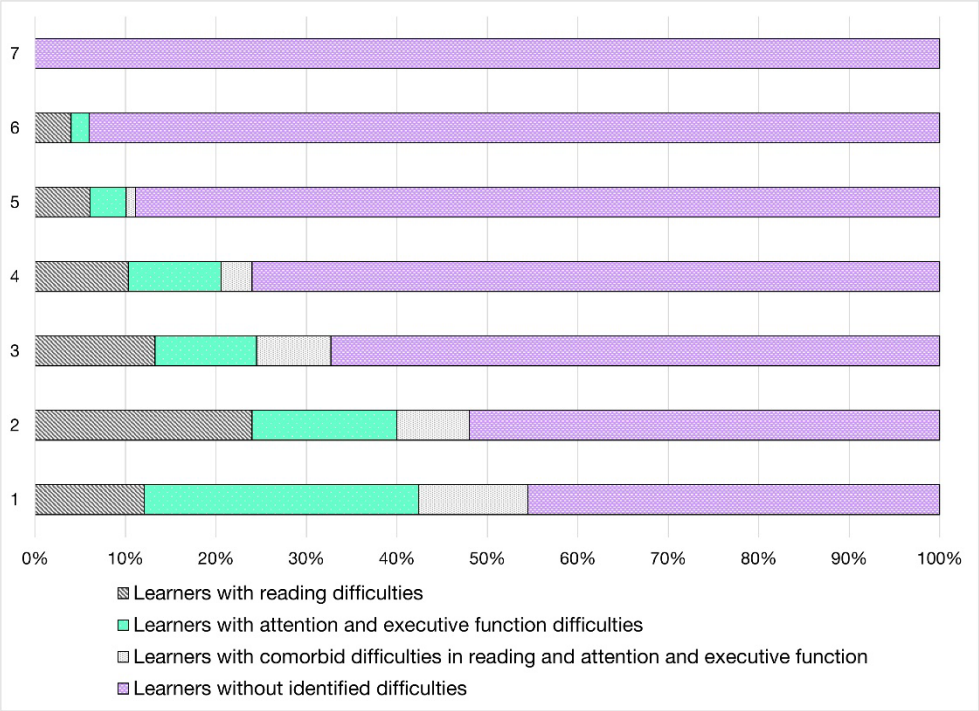

FIGURE 4 Online research and comprehension performance profiles by students' learner groups. (1) very poor performers, (2) poor performers, (3) below-average performers, (4) average performers with low questioning credibility scores, (5) average performers, (6) good performers, and (7) top performers.

4 GENERAL DISCUSSION

This doctoral dissertation aimed to shed light on elementary school students' online research and comprehension performance. Students are often required to complete school-related research tasks on the Internet and to locate, evaluate, synthesize, and communicate online information, skills that are becoming increasingly important in the age of digitalization (Leu et al. 2019). The first aim of this dissertation was to examine the extent to which learners' literacy skills (reading fluency, written spelling, and reading comprehension), reading habits, nonverbal reasoning ability, and prior topic knowledge were associated with their online research and comprehension performance (Study I, Study III). Second, this dissertation aimed to examine interindividual differences in students' online research and comprehension performance among learners with reading difficulties and/or difficulties in attention and executive function (Study II, Study III). The third aim of this dissertation was to evaluate the gender effect in association with learners' online research and comprehension performance, including students with learning-related difficulties (Study I, Study II). Studies I–III were carried out among sixth-grade students, and the following sections present a detailed discussion of the findings and their theoretical, methodological, and practical implications.

4.1 Literacy-related skills and knowledge in association with learners' online research and comprehension performance

First, the findings (Study I) showed that reading comprehension was the strongest predictor of learners' common online research and comprehension performance. This means that the better students' reading comprehension was, the better they were in reading to learn from online information. This is consistent with previous research (Coiro, 2011; Leu et al., 2015; Salmerón et al., 2018). In addition, the findings also showed that reading comprehension was associated with all separate component skills except locating information. It may be that the

current assessment, in which students were given specific instructions for locating tasks, required more understanding of how search engines work than comprehension skills. In more open locating tasks, in which readers need to comprehend the task assignment to formulate relevant search queries, reading comprehension may play a bigger role.

Second, in addition to reading comprehension, learners' lower-level literacy skills (reading fluency and written spelling) were unique predictors for common online research and comprehension performance. The predictive power of reading fluency and written spelling was similar in relation to the common online research and comprehension, but in relation to the separate component skills, the role of written spelling increased over reading fluency. Specifically, reading fluency was only associated with communicating information, whereas written spelling was associated with locating, synthesizing, and communicating information. Previous research on these lower-level literacy skills and online research and comprehension is somewhat contradictory. For example, Rouet et al. (2011, experiment 2) found that both elementary and middle school students' reading fluency was associated with their web page selection on a simulated search engine result page. Further, Macedo-Rouet et al. noticed that both elementary school (2013, experiment 1) and secondary school students' (2020) word recognition skills were associated with their information source selection, a prerequisite for successful evaluation of information. However, students' reading comprehension scores were not included in the same analyses in these studies. Hahnel et al. (2018) did not find this kind of relation between word recognition and the evaluation of information over adolescents' reading comprehension skills. Then again, Hahnel et al. measured only one online research and comprehension component: evaluation skill. Florit et al. (2019) found that reading fluency was not associated with children's information source selection skills. Nevertheless, they found that fluency was associated with the students' multiple document comprehension, which has in common with synthesizing and communicating information from multiple texts.

It seems that in this thesis the role of fluency and written spelling was higher in students' overall online research and comprehension performance than in separate component skills. Task completion in the simulated closed Internet environment required written responses, and thus, it may have highlighted students' written spelling skills. In the open Internet, the role of reading fluency could also increase when the complexity of online texts increases, such as with hyperlinks and multimodal elements, and construction of reading paths may take more time. On the other hand, many search engines suggest corrections to misspellings on the open Internet, which could diminish the predictive power of written spelling, for example, in relation to locating information. Thus, more research is needed to examine lower-level literacy skills comprehensively across all the online research and comprehension component skills, especially on the open Internet.

Third, nonverbal reasoning ability contributed independently to learners' common online research and comprehension performance and was also found to

be associated with the component skills of identifying main ideas and communicating information. This finding is in line with prior research suggesting a supportive role for nonverbal reasoning in reading comprehension (Swart et al., 2017; Peng et al., 2018). In particular, the communication component required reasoning skills because learners were asked to form a recommendation and justify it with reasoning that represented different perspectives covered in the online texts. Further, the role of inferential processes (Duke & Cartwright, 2021; Kendeou et al., 2016) and nonverbal reasoning (Adlof et al., 2010; Swart et al., 2017) increases when learners need to answer comprehension questions that require problem solving, which was the case in the online research and comprehension assessment task used in this dissertation thesis.

Fourth, prior topic knowledge was not a significant predictor of students' online research and comprehension performance in this dissertation. Reading comprehension and knowledge seem to have a reciprocal relationship in which knowledge supports comprehension but comprehension also supports the use of knowledge (for a review, see Cervetti & Wright, 2020). Sixth-grade students may not necessarily have been skilled enough readers to draw on their prior topic knowledge in a complex, web-based reading environment, or they did not have enough information concerning the topic (health effects of energy drinks). For instance, Forzani (2016) found a weak relation between seventh-grade students' prior topic knowledge and evaluation of information, but Florit et al. (2019) did not find such relations between younger readers'—more precisely, fourth-grade students'— prior topic knowledge and multiple document comprehension. On the other hand, Amadieu et al. (2009) and Kammerer et al. (2021) found a relation between university students' prior topic knowledge and their online reading performance. However, these contradictory findings might also be related to how prior topic knowledge was tested (McCarthy & McNamara, 2021). The testing of knowledge is not easy, especially when testing specific items of complex science topics that may not form a single construct (Taber, 2018).

Finally, the findings (Study III) also showed that learners' reading habits, especially reading longer and versatile texts both on paper and on digital formats, were associated with their online research and comprehension performance profiles. Notably, reading books had the strongest association with learners' online research and comprehension performance profiles over reading newspapers, magazines, and comics. Further, reading blog posts and ebooks was also positively associated with learners' online research and comprehension performance level, whereas reading online newspapers, websites, and online forum posts, however, had no associations. This means that good and top performers seemed to read more books, ebooks, and blog posts than very poor and poor performers but, for example, did not differ from each other in reading comics and online forum posts. This is consistent with traditional reading research that has shown strong relations between reading frequency for books and reading comprehension levels over that for other reading materials (Pfost et al., 2013; Spear-Swerling et al., 2010; Torppa et al., 2020).

However, the contrary is that traditional reading research has shown negative associations between learners' digital reading habits and their reading comprehension performance (Pfost et al., 2013; Torppa et al., 2020). This contradictory finding may relate to the fact that traditional reading research has seen digital reading habits somewhat narrowly. For instance, Pfost et al. (2013) and Torppa et al. (2020) included reading materials such as emails, instant messages, and online forum posts that mainly present social online engagement. Further, even though 12–13-year-olds of this dissertation did not, for instance, differ in reading online news, and read ebooks quite rarely, reading these kinds of digital materials may become a stronger predictor among older students. Naumann (2015), for example, found a positive relation between 15-year-olds' information engagement, such as reading online news and searching for information on the Internet, and their navigation behavior—i.e., the number of learners' visits and re-visits to task-relevant webpages. Moreover, Jang et al. (2021) have shown that learners' attitudes toward print and digital reading are often changeable, and older students seem to prefer digital media. With all of this said, text length and richness seem to matter more than reading medium.

4.2 Learners with reading difficulties and/or difficulties with attention and executive function struggle in online research and comprehension

The second aim of this dissertation was to examine interindividual differences in students' online research and comprehension performance among learners with reading difficulties and/or difficulties with attention and executive function. Study I already highlighted the importance of literacy skills, both lower-level skills (reading fluency and written spelling) and higher-level skills (reading comprehension). Namely, the linear relationships of learners' literacy skills to their online research and comprehension performance predicted that those with below-average reading fluency, written spelling, or reading comprehension are also very likely to have difficulties in web-based reading environments. Study III and the person-centered approach, precisely latent profile analysis, confirmed this assumption by showing that 59% of learners with reading difficulties belonged to the three lowest online research and comprehension performance profiles. This finding is aligned with traditional reading research showing that difficulties in decoding and reading fluency are often associated with difficulties in reading comprehension (e.g., Hulme et al., 2015; Lyon et al., 2003). Moreover, recent review studies (Galuschka et al., 2020; Reis et al., 2020) have shown that difficulties in written spelling and writing are very common among learners with reading difficulties. It seems that complex web-based reading environments set an extra demand on learners with reading difficulties, especially when text and knowledge construction require written responses.

Study II showed that this was also the case for learners with difficulties in attention and executive function, who faced more difficulties in the complex online research and comprehension environment than in the more simplified multiple-choice reading comprehension task on the paper. After controlling for the main effects of gender (e.g., differences in means), reading fluency, and nonverbal reasoning, learners' difficulties in attention and executive function did not affect their performance in reading comprehension. However, after controlling for the aforementioned background variables and reading comprehension in the multiple-choice task, learners' attention and executive function difficulties explained their performance in a web-based reading environment. Findings from Study III showed that 67.5% of the learners with attention and executive function difficulties belonged to the lowest three performance profiles. Notably, the proportion of learners with attention and executive function difficulties (30.3%) among very poor performers was higher than the proportion of learners with reading difficulties (12.1%). Learners' comorbid difficulties in reading as well as attention and executive function caused the most severe difficulties in their online research and comprehension performance: 82.4% of the learners with comorbid difficulties belonged to the lowest three performance profiles.

These findings show that difficulties in reading as well as in attention and executive function play an important role when using the Internet for solving problems and representing solutions. Creating meaning from multiple online texts seems to demand more than processing a single linear text (see also Cho & Afflerbach, 2017). During the online research and comprehension assessment used in this dissertation, learners were required to read information from four different online texts. Specifically, learners were required to focus and shift their attention between different component skills, such as critical evaluation of information and synthesizing information across multiple online texts. Moreover, they were also required to focus on and shift between different kinds of tools, such as a search engine, a social networking site, and a notetaking tool. It may be that learners' working memory capacity was overburdened and lacked space for planning and writing versatile answers. Successful meaning construction in written responses 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).

It is noteworthy that the proportion of learners with difficulties in attention and executive function in the profile of very poor performers was much higher than the proportion of learners with reading difficulties. Learners with reading difficulties had poor reading fluency skills. Learners with teacher-rated attention and executive function difficulties faced challenges in, for instance, focusing attention on instructions and completing tasks. Difficulties in attention and executive function seem to be more severe in nature than difficulties in reading when studying and learning from online information. Further, difficulties in attention and executive function might even play a bigger role in the open Internet, where online texts are often also hyperlinked, and contain distractors,

such as pop-up advertisements. Additionally, those learners with comorbid difficulties in reading and attention and executive function may be in need of extreme support on the open Internet. Thus, future research needs to investigate the effects of learners' difficulties in reading as well as in attention and executive function in relation to their online research and comprehension performance when accessing the open Internet.

On the other hand, a couple of learners with reading difficulties (25.7%) or difficulties in attention and executive function (16.2%) performed better than expected based on their deficiencies. This finding is particularly important, as it suggests that these learners might have developed some compensatory strategies to overcome the challenges of online reading. For instance, small case studies by Castek et al. (2011) and Henry et al. (2012), found that web-based reading environments can provide comprehension support for learners with reading difficulties by providing non-textual elements, such as pictures and videos, making learners less dependent on their reading skills. However, Andresen et al. (2019a) showed that learners with reading difficulties seemed not to use these kinds of elements more often than learners without such difficulties. In another interesting prior study, Leinonen et al. (2001) found that some adult learners with reading difficulties reported reading a large number of books per year, which seemed to enhance their lexicon. In this dissertation, the finding that good online research and comprehension performers reported reading books more frequently than, for example, very poor and poor performers may indicate that reading longer and more vocabulary-rich texts could be one compensatory mechanism for those above-average performing readers with learning-related difficulties. However, more research is needed to understand learners' possible compensatory strategies and mechanisms for overcoming their reading difficulties or difficulties in attention and executive functions when working with online information. This understanding could help teachers and educators in designing instructions for the needs of learners struggling with online research and comprehension.

4.3 Girls outperform boys in online research and comprehension

The third aim of this dissertation was to evaluate the gender effect in association with learners' online research and comprehension performance, including those with learning-related difficulties. Study I showed that, on average, girls outperformed boys in the common online research and comprehension performance, as well as in the online research and comprehension component skills such as questioning the credibility of information in less credible texts, identifying main ideas from a single online text, synthesizing information across multiple online texts, and communicating a well-justified and source-based position. Although girls and boys did not differ in the component skills of locating information with a search engine and confirming the credibility of information in more credible texts, the gender effect on learners' common online

research and comprehension performance and most of the component skills is consistent with previous findings concerning web-based reading environments (Forzani, 2016; Naumann & Sälzer, 2017; Salmerón et al., 2018). Notably, locating information with a search engine might be perceived as relating to a more technology-related activity. Moreover, even though Caccia et al. (2019) did not identify such a relation among Italian adolescents, large-scale international studies, for example, the PISA digital reading assessment, have discovered the gender effect favoring girls' when reading to learn from online information (Brozo et al., 2014).

Further, it is important to take into account that although Finland and Italy were not among the 19 countries participating in this PISA digital reading assessment (OECD, 2011), the gender gap between girls and boys in traditional literacy skills in Finland is twice as wide as in Italy (OECD, 2019). Thus, at least in the Finnish context, boys who are struggling in their literacy skills may also be struggling in online research and comprehension. However, Study I interestingly showed that the gender variable had a direct effect beyond the indirect effects via literacy skills and other predictors. Therefore, there are also other gender-related differences that could explain why girls performed better than boys in online research and comprehension than learners' differences in traditional literacy skills. For example, compelling evidence seems to show that girls have more positive motivation for traditional reading than boys (Kavanagh, 2019; Wigfield & Guthrie, 1997) and that reading engagement seems to mediate their higher reading scores (Chiu & McBride-Chang, 2006). This might especially be the case in Finland, where the gender difference in reading engagement is one of the widest among OECD countries (Brozo et al., 2014). Thus, the role of motivation for reading to learn from online information seems to be an important aspect to explore in future work.

It is also worth noting that difficulties in attention and executive function were associated more with girls' than with boys' online research and comprehension performance. These difficulties explained 9% of girls' online research and comprehension performance and 4% of boys' performance. This finding is contrary to previous research showing that boys with attention difficulties are more likely to be identified as having reading difficulties than girls with attention difficulties (Biederman et al., 2002). This may indicate that boys' online research and comprehension skills could be more dependent on other factors than attention and executive function. Once again, motivational factors can be highlighted, but it remains for future studies to explore more possible reasons for the observed gender difference.

4.4 Theoretical, methodological, and practical implications

This dissertation expands our theoretical and methodological knowledge of online research and comprehension (Kiili et al., 2018b; Leu et al., 2004; Leu et al., 2019). First, our understanding is extended and refined by showing that learners'

online research and comprehension performance form a common entity. Further, the strong association between literacy skills and this common entity of online research and comprehension seem to strengthen the theoretical arguments of the expected layers, such as the Simple View of Reading (e.g., Gough & Tunmer, 1986), the Construction-Integration Model (Kintsch, 1998), and the Multiple Documents Framework (Perfetti et al., 1999), behind reading for learning on the Internet. This means that the better students' literacy skills are, the better they seem to perform in web-based reading environments.

Second, the online research and comprehension component skills, especially locating information and questioning the credibility of information in the less credible texts, also had variance not captured by the common structure. Thus, depending on the purpose of future studies, learners' online research and comprehension performance could be examined by using either a general online research and comprehension construct or a more detailed component skill structure based on the theoretical framework. Showing that not all literacy skills predicted all the component skills, strengthens the theoretical arguments of the specific nature of Online Research and Comprehension Framework (Leu et al., 2004; Leu et al., 2019). Beyond literacy skills, locating information may require specific knowledge of how to use a search engine or questioning the credibility of information may require encouragement to express discrepancies in less credible texts. Consequently, the components of identifying main ideas from a single text and synthesizing these ideas from multiple texts to communicate information with others seem to be closer to traditional literacy skills than locating and evaluating components.

Third, our understanding of the learners' online research and comprehension performance is extended by showing that the examination of learners' performance can also be conducted with a person-centered approach, which produced information not obtained by other approaches. Namely, when examining learners' online research and comprehension performance with a latent profile analysis, it can be seen that the seven profiles captured learners' performance levels from very poor performers to top performers. In other words, the profiles mainly reflected learners' performance levels across all six online research and comprehension component skills. This is to say that learners belonging to very poor performers or poor performers struggled more or less with all component skills, whereas good and top performers were quite skilled or skilled in all areas. Although this largely ordinal ordering of the profiles could have been revealed already with the variable-centered analyses, the person-centered approach enabled me to show that there also were learners who performed better than could be expected based on their deficiencies and learners who faced difficulties online without having any identified difficulties in their literacy skills or attention. The theoretical layers from lower-level literacy skills toward online research and comprehension skills seem to overlap (Figure 5).

The one exceptional profile, the average performers with low questioning credibility scores, showed that online texts that are biased or lack expertise may be particularly challenging for some young learners, which is in line with

previous research (Kiili et al. 2018a; Pérez et al., 2018). One future direction to extend our understanding of learners' differences in their ability to question the credibility of biased information could be multilevel latent profile analysis. In this dissertation (Study III), multilevel latent profile analysis was applied to examine whether the proportional distributions of single-level online research and comprehension profiles varied across classrooms. However, statistically significant differences were not found as a function of learners' classrooms. Nevertheless, these kinds of multilevel differences may be possible with a larger sample and grade level. For instance, it remains for future work to explore whether single-level online research and comprehension profiles vary on a continuum from the elementary-school level to the secondary-school level. Further, also longitudinal research is needed to examine the development of learners' online research and comprehension performance.

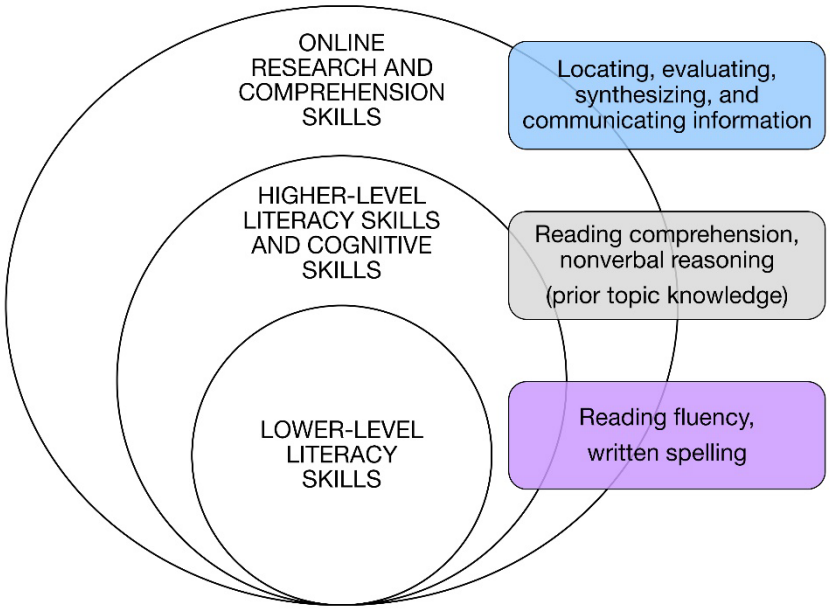

FIGURE 5 From lower-level literacy skills toward online research and comprehension skills needed in complex web-based reading environments

The key practical implications of this dissertation are that literacy skills seem to form the crucial foundation for successful online research and comprehension, and thus students with difficulties related to their reading and learning also seem to face challenges online (Studies I–III). However, it seems that learners with reading difficulties and difficulties with attention and executive function may still be literate on the Internet, whereas learners without these kinds of identified difficulties may still be ill-equipped to confront the new skill demands of web-based reading environments. Since the role of technology in reading and learning has increased in our daily lives, it is important to be aware that people are reading to learn from online information at younger and younger ages.

Hence, teachers and educators should be aware that, as literacy skills partly overlap with online research and comprehension component skills, instruction supporting learners' literacy skills is important but not sufficient for educating successful online readers. For instance, reading vocabulary-rich texts both on paper and digital is necessary, and learners may benefit from instructions that are relevant to both traditional reading and online research and comprehension. Thus, effective comprehension strategies that can be applied in the context of both single and multiple texts are important (Britt et al., 2018; Cho & Afflerbach, 2015). Further, learners also need to know how to form and enter relevant search terms into a search engine (Leu et al., 2019), and how to identify the author of an online text and evaluate why he or she has written the text (Cho & Afflerbach, 2015). Learners also need instruction on evaluating and using online texts that vary in their perspectives, interpretations, and genres (Britt et al., 2018). Instruction focusing on effective locating and evaluation strategies would help learners with reading difficulties and/or attention difficulties become more skilled in these areas. Being able to efficiently locate and evaluate online information would also increase resources dedicated to making sense of actual online texts.

However, reading multiple online texts may still be overwhelming, especially for students with learning-related difficulties, and they may need more time and effort for reading compared to their classmates. Hence, it might also be pedagogically meaningful to divide the practice of online research and comprehension component skills into more manageable parts. Guided practice in which learners can integrate ideas from a limited number of texts, starting from two different texts, would ensure more resources for practicing the specific component skills needed. For instance, comparing, and contrasting texts and forming ties between ideas originating from different online texts in order to write a synthesis. Moreover, texts can also be printed and read on paper. Especially for learners with attention and executive function difficulties, it may be beneficial to practice online research and comprehension component skills without having to be worried about constant interruptions of irrelevant distractors, such as advertisements and pop-up windows.

Previous research has shown that while learners with difficulties in attention have a greater need for stimulation, it is important that the stimulation is task-relevant and can help them inhibit negative distractors (Raggi & Chronis,

2006). In contrast to the open Internet, structured practice of online research and comprehension component skills may allow learners to focus their attention on just one aspect at a time. Further, developing and designing structured web-based environments with positive distractors, such as prompts and feedback, instead of irrelevant ones may also be crucial to engage these learners in online reading activities. Overall, greater emphasis should be placed on designing interventions for learners with reading difficulties and/or difficulties with attention and executive function that support their learning from online information.

Finally, it is important to note that there were students without the identified learning-related difficulties who nonetheless had significant challenges in their online research and comprehension performance. This indicates the importance of additional work designed to understand what causes these learners' poor performance. For example, aspects such as boredom and frustration have been speculated to cause poor performance in multiple text reading if learners end up interrupting their task execution too early (List & Alexander, 2019), but this remains for future work to investigate.

4.5 Limitations and future directions

As with every dissertation, this one is not without limitations. However, limitations often shed light on avenues for future work. First, learners' online research and comprehension performance was assessed in the simulated Internet environment that was a closed, scaffolded information space. For example, if a student failed the locating task, the avatar offered the link to the correct online text. However, learners are not typically provided with correct online texts in real-world online reading situations in which they use search engines on the open Internet. Thus, learners' literacy skills (reading fluency, written spelling, and reading comprehension), reading habits, nonverbal reasoning ability, and prior topic knowledge, may play somewhat greater roles in the open Internet, which is a more complex information space. Even though this remains for future work to investigate, teachers and educators should be aware of the overestimation possibility of learners' online reading skills and, for instance, pay close attention to how poor locating skills can influence different learner groups' performance more on the open Internet. Students may quit the task faster if they get frustrated and are unable to locate relevant information. Further, a 45-minute class period is most likely not long enough to complete this kind of complex online research and comprehension task without such prompts and guidance included in the ILA/ORCA assessment. Still, it is noteworthy that this task design allows for investigation of learners' performance in the other online research and comprehension component skills (e.g., evaluation of the credibility of information) without the consequence of failing to find the right webpages—i.e., as independent separate component skills.

Second, in this dissertation, learners' diagnoses, such as dyslexia and ADHD diagnoses, were not available for most of the participating students. As a formal diagnosis is not a prerequisite for special educational support in Finland, not all students with such difficulties have a diagnosis. For some students, the parents reported that reading difficulties and/or difficulties in attention had been identified. In addition, the number of participants with reading and/or attention and executive function difficulties was in line with the prevalence of these difficulties: 5–15% of school-age children struggle with such difficulties (American Psychiatric Association, 2018). Moreover, the measures used to divide students into learner groups met the characteristics displayed for reading difficulties, such as inaccurate, poor word recognition and decoding skills (Lyon et al., 2003), and also showed good criterion validity (Klenberg et al., 2010b) with the ADHD Rating Scale–IV: School Version (DuPaul et al., 1998).

Third, the prior topic knowledge measure had the relatively low McDonald's omega reliability, and thus was excluded from the analyses after Study I. It seemed that either alpha's or omega's assumptions related to unidimensionality did not hold (see, e.g., McNeish, 2018; Savalei et al., 2019). It is still worth noting that this is somewhat common in tests of knowledge (Taber, 2018). For instance, Forzani (2016) and List (2021) have also reported very low alphas for knowledge tests. Tests of knowledge usually include various specific items in order to test different knowledge components, especially for complex science topics, may not form a single construct (Taber, 2018).

Finally, the time was limited in schools, and thus, multiple cognitive components, such as working memory and vocabulary, were not examined in association with online research and comprehension. In future work, it may also be interesting to access process data, such as verbal protocols and response times, to explore the online research and comprehension strategies of different learner groups, especially those with reading difficulties and/or difficulties with attention and executive function. Extending the time available could already influence students' performance if they stay motivated. Motivational factors were not included in the studies conducted in this dissertation, although, for example, List and Alexander (2017) have theorized the importance of motivational factors when reading to learn from multiple texts. Motivational factors, such as learners' interests, values, and self-efficacy—i.e., beliefs about their capabilities—have also been shown to play a role when reading to learn from multiple online texts (Forzani et al., 2021). Given theorizing and extant research give a reason to believe that motivational factors may also play an important role when readers with learning-related difficulties are working with online texts. Motivational factors might also shed light on gender differences between girls and boys. However, addressing these questions beyond speculation remains for future work.

4.6 Conclusions

Overall, this dissertation thesis broadens our understanding of the elementary school students' online research and comprehension performance, especially by including learners with difficulties in reading and/or difficulties with attention and executive function. The confirmed factor structure of common online research and comprehension performance and the online research and comprehension components skills strengthen the theoretical foundation of the Online Research and Comprehension Framework (Kiili et al., 2018b; Leu et al., 2004; Leu et al., 2019). Moreover, literacy skills seem to form the basis of online research and comprehension without forgetting reasoning skills and attentional and executive function processes. The classified seven latent online research and comprehension performance profiles, from very poor performers to top performers, help teachers and educators develop supporting strategies for various levels of online readers. Not unexpectedly, learners with difficulties related to their reading skills and/or attention and executive functions seem to perform generally lower in online research and comprehension than learners without these kinds of difficulties. However, some students—though very few—perform better than would be expected based on their deficiencies. Further knowledge of these well-performing learners with reading/attention difficulties as well as low-performing learners without identified difficulties would be very important, particularly to explore compensatory mechanisms and strategies as well as to design supportive pedagogical activities for all learners.

YHTEENVETO (SUMMARY)

Tutkivan nettilukemisen taidot alakoululaisilla: Lukivaikeuksien sekä tarkkaavuuden ja toiminnanohjauksen vaikeuksien merkitys

Lapset ja nuoret surffaavat Internetissä tottuneesti, mutta taitava nettilukeminen ei rakennu pelkän surffailun varaan. Tutkivan nettilukemisen taitoihin luetaan (1) kysymysten asettaminen, (2) tiedonhaku ja (3) lähteiden kriittinen arviointi sekä (4) taito yhdistellä yksittäisiä tietoja useamman eri lähteen pohjalta synteesiksi ja (5) taito jakaa oppimaansa muiden kanssa (Leu ym., 2004; 2019). Koska nämä osataidot edellyttävät kykyä lukea ja kirjoittaa, tutkivan nettilukemisen voidaan olettaa rakentuvan peruslukutaitojen, kuten kirjain-äännevastaavuuden, lukusujuvuuden, oikeinkirjoituksen ja luetun ymmärtämisen taitojen varaan (Duke & Cartwright, 2021; Gough & Tunmer, 1986; Hoover & Gough, 1990; Hoover & Tunmer, 2018; Perfetti & Stafura, 2014). Perinteisen lukemisen tutkimus on osoittanut, että luetun ymmärtämisen taitojen karttuessa lukija pystyy muodostamaan kokonaiskuvan niin yksittäisestä tekstistä (Kintsch, 1998) kuin useammastakin eri tekstistä (Perfetti et al., 1999; Strømsø, 2017). Lukiessaan useampaa tekstiä lukijan täytyy kuitenkin huomioida myös tekstien yhtäläisyydet ja mahdolliset ristiriidat, mikä on yleistä varsinkin nettiteksteissä (Britt & Gabrys, 2002; Pérez et al. 2018). Luku- ja kirjoitustaidon lisäksi nettilukeminen vaatii myös teknistä osaamista, kuten kykyä käyttää hakukonetta tai kykyä navigoida selainikkunassa. Jos lukemisen perusta horjuu, on hyvin todennäköistä, että oppilaalla on vaikeuksia myös netissä lukiessaan. Oppimisvaikeuksien yhteyksistä nettilukemiseen tiedetään kuitenkin vielä varsin vähän, eikä peruslukutaitojenkaan, kuten lukusujuvuuden tai oikeinkirjoitustaidon, yhteyksiä tutkivan nettilukemisen kaikkiin osataitoihin ole vielä kattavasti tutkittu.

Väitöskirjan osatavoitteena I olikin selvittää, miten oppilaiden peruslukutaidot (lukusujuvuus, oikeinkirjoitustaito, luetun ymmärtäminen), lukutottumukset, ei-kielellinen päättelykyky sekä aiemmat ennakkotiedot ovat yhteydessä heidän suoriutumiseensa tutkivan nettilukemisen tehtävässä (Osatutkimus I ja III). Hypoteesiksi I asetettiin, että oppilaan luetun ymmärtämisen taidot, lukutottumukset, ei-kielellinen päättelykyky sekä aiemmat ennakkotiedot aiheesta ovat yhteydessä oppilaan suoriutumiseen nettilukutehtävässä. Lukusujuvuuden ja oikeinkirjoituksen osalta ei asetettu hypoteeseja aiemman tutkimuksen puuttuessa. Osatavoitteena II oli selvittää, miten lukemisen vaikeudet ja/tai tarkkaavuuden ja toiminnanohjauksen vaikeudet ovat yhteydessä oppilaiden suoriutumiseen nettilukutehtävässä (Osatutkimus II ja III). Hypoteesiksi II asetettiin, että oppimiseen liittyvät vaikeudet ovat yhteydessä oppilaiden suoriutumiseen myös netistä luettaessa. Osatavoitteena III selvitettiin vielä sukupuolten välisiä eroja mukaan lukien oppilaat, joilla oli oppimiseen liittyviä vaikeuksia (Osatutkimus I ja II). Hypoteesiksi III asetettiin, että tytöt pärjäisivät nettilukutehtävässä poikia paremmin.

Kaikki kolme osatutkimusta ovat osa Suomen Akatemian rahoittamaa *Internet ja oppimisvaikeudet: Monitieteinen lähestymistapa tiedon hankkimiseen uudessa mediassa* -hanketta (eSeek; PI Paavo H.T. Leppänen; 2014–2017). Perinteisten paperilukutehtävien, päättelytehtävän (ei-kielellinen päättelykyky) sekä lukutottumuksia kartoittavan kyselylomakkeen ohella oppilaat tekivät tutkivan nettilukemisen tehtävän Internetiä simuloivassa tehtäväympäristössä. Suomenkielinen tehtäväympäristö pohjautuu Yhdysvalloissa kehitettyyn ja validoituun nettilukemisen tehtäväympäristöön (ORCA; Leu ym. 2015). Tehtäväympäristössä kuvitteellisen koulun rehtori pyytää sähköpostilla, että oppilaat selvittävät energiajuomien terveysvaikutuksia sekä esittävät perustellun kantansa siihen, pitäisikö koululle hankkia energiajuoma-automaattia vai ei. Tehtävän aikana oppilaat lukevat neljä eri nettitekstiä: kaksi uutistekstiä, akateemisen tietotekstin ja kaupallisesti värittyneen tekstin. Oppilaat saavat valmiina kaksi nettitekstiä ja kaksi he etsivät itse hakukoneen avulla. Lisäksi oppilaat arvioivat kahden nettitekstin luotettavuutta. Kun oppilaat ovat lukeneet nettitekstit, he laativat lyhyen yhteenvedon eli synteesin oppimastaan ja lähettävät perustellun kantansa rehtorille sähköpostitse. Oppilaiden aiempia ennakkotietoja energiajuomien terveysvaikutuksista kysytään nettilukutehtävän alussa.

Osatutkimukseen I osallistui 426 kuudesluokkalaista oppilasta (207 tyttöä, 12–13 vuotta). Konfirmatorinen faktorianalyysi osoitti, että tutkiva nettilukeminen jakaantui kuuteen osataitoon, jotka myös muodostivat toisen kertaluvun faktorin eli yhtenäisen tutkivan nettilukemisen kokonaisuuden. Tulokset tukevat nettilukemisen teoreettista mallia, mutta lähteiden kriittinen arviointi koostui kahdesta erillisestä osataidosta: tekstin luotettavuuden vahvistamisesta ja tekstin luotettavuuden kyseenalaistamisesta. Tämän lisäksi synteesin laatiminen jakautui kahteen osaan: synteesin kirjoittamista valmistelevaan pääasioiden poimimiseen yksittäisistä teksteistä ja eri lähteistä saadun tiedon yhteen nivomiseen. Hypoteesin I mukaisesti rakenneyhtälömallinnus osoitti, että luetun ymmärtäminen ja ei-kielellinen päättelykyky olivat yhteydessä tutkivaan nettilukemiseen. Lisäksi lukusujuvuus ja oikeinkirjoitustaito selittivät oppilaiden tutkivan nettilukemisen tehtävässä suoriutumista. Sen sijaan, oppilaiden aiemmilla ennakkotiedoilla energiajuomista ei ollut yhteyttä nettilukutehtävässä suoriutumiseen. Luetun ymmärtäminen oli selkeästi vahvin selittävä tekijä, sillä vaihtoehtoisessa rakenneyhtälömallissa luetun ymmärtäminen oli suoraan yhteydessä kaikkiin muihin osataitoihin paitsi tiedonhakuun. Lukusujuvuuden ja oikeinkirjoituksen suorat yhteydet sekä nettilukemisen osataitoihin että kokoavaan tutkivan nettilukemisen kokonaisuuteen osoittavat, että peruslukutaidot luovat pohjaa tutkivalle nettilukemiselle. Hypoteesin III mukaisesti kuudesluokkalaiset tytöt näyttivät pärjäävän nettilukemisen tehtävässä kuudesluokkalaisia poikia paremmin.

Osatutkimuksessa II tarkasteltiin samaa 426 kuudesluokkalaisen joukkoa. Rakenneyhtälömallinnuksen avulla tarkasteltiin, vaikuttavatko tarkkaavuuden ja toiminnanohjauksen vaikeudet oppilaiden suoriutumiseen enemmän luetun ymmärtämisen monivalintatehtävässä (paperitehtävä) vai tutkivan

nettilukemisen tehtävässä. Lisäksi vertailtiin sukupuolten välisiä eroja tehtävissä. Hypoteesin II mukaisesti oppilailla, joilla oli tarkkaavuuden ja toiminnanohjauksen vaikeuksia, oli enemmän haasteita netissä tehdyssä tutkivan nettilukemisen tehtävässä kuin paperilla tehdyssä luetun ymmärtämisen monivalintatehtävässä. Tarkastelussa kontrolloitiin oppilaiden sukupuoli, lukusujuvuus ja ei-kielellinen päättelykyky sekä nettilukemisen osalta myös luetun ymmärtäminen monivalintatehtävässä. Hypoteesista III poiketen, tytöillä, joilla oli tarkkaavuuden ja toiminnan ohjauksen vaikeuksia, oli tutkivan nettilukemisen tehtävässä enemmän haasteita kuin pojilla, joilla oli vastaavia vaikeuksia.

Osatutkimus III koostui myös samasta 426 kuudesluokkalaisen perusjoukosta, minkä lisäksi tutkimusjoukkoa kasvatettiin oppilailla, joilla oli lukemisen ja/tai tarkkaavuuden ja toiminnanohjauksen vaikeuksia. Näin pyrittiin varmistamaan, että oppimiseen liittyvien vaikeuksien esiintyvyys lopullisessa 436 kuudesluokkalaisen aineistossa vastaa näiden vaikeuksien keskimääräistä esiintyvyyttä populaatiossa. Latentin profiilianalyysin tulokset osoittivat, että tutkivan nettilukemisen osataidot jakaantuivat seitsemään nettilukemisen suoriutumisprofiiliin erittäin heikosti suoriutuvista erinomaisesti suoriutuviin. Profiilit pohjautuivat pääasiassa tasoeroihin, lukuunottamatta profiilia, johon kuuluvilla oppilailla oli vaikeuksia arvioida kaupallista nettitekstiä, vaikka he muutoin suoriutuivat nettilukemisen tehtävässä keskimääräisesti.

Tarkasteltaessa lukutottumusten yhteyttä nettilukemiseen, havaittiin, että pitkien, kielellisesti rikkaiden tekstien, kuten kirjojen ja blogien lukeminen, oli yhteydessä nettilukutehtävässä menestymiseen. Sitä vastoin lyhyempien tekstien, kuten sarjakuvien tai keskustelupalstaviestien, lukeminen ei ollut yhteydessä oppilaiden suoriutumiseen. Tämä tuki hypoteesia I. Oppilaista, joilla oli lukemisen vaikeuksia ja/tai tarkkaavuuden ja toiminnanohjauksen vaikeuksia, reilusti yli puolet sijoittui kolmeen heikoimpaan suoriutumisprofiiliin, mikä taas tuki hypoteesia II. Mielenkiintoista on kuitenkin se, että 25.7 % oppilaista, joilla oli lukemisen vaikeuksia, ja 16.2 % oppilaista, joilla oli tarkkaavuuden ja toiminnanohjauksen vaikeuksia, sijoittuivat keskimääräisesti tai hyvin suoriutuviin profiileihin oppimiseen liittyvistä vaikeuksistaan huolimatta. Kiinnostavaa on myös se, että heikosti suoriutuvien profiileissa oli oppilaita, joilla ei ollut tunnistettuja oppimiseen liittyviä vaikeuksia, mutta joilla kuitenkin selkeästi oli vaikeuksia nettilukutehtävässä.

Kokonaisuudessaan väitöstutkimuksen tulokset osoittivat, että tutkivan nettilukemisen osataidot rakentuvat peruslukutaitojen (lukusujuvuus, oikeinkirjoitustaito, luetun ymmärtäminen) varaan. Pitkien, kielellisesti rikkaiden tekstien lukeminen niin paperilta kuin digitaalisesti näytti vahvistavan tätä perustaa ja tuki näin lukijoita myös tutkivassa nettilukemisessa. Oppilailla, joilla oli oppiseen liittyviä vaikeuksia, oli nettilukutehtävässä enemmän haasteita kuin oppilailla, joilla ei ollut lukemisen tai tarkkaavuuden vaikeuksia. On kuitenkin tärkeää muistaa, että näin ei ollut kaikkien kohdalla. Esimerkiksi lukutottumukset voivat kompensoida oppimiseen liittyviä vaikeuksia.

Jatkotutkimusta muista mahdollisista kompensaation keinoista, kuten sanavaraston ja työmuistin merkityksestä, kuitenkin tarvitaan. Samoin tarvitaan jatkotutkimusta tyttöjen ja poikien välisistä eroista nettilukutaidoissa. Tytöt näyttivät pärjäävän poikia paremmin, mutta erot peruslukutaidoissa selittivät tätä vain osittain. Huomiota voitaisiin kiinnittää myös mahdollisiin motivaatioeroihin tyttöjen ja poikien välillä.

Kaiken kaikkiaan tämän väitöstutkimuksen tulokset osoittavat, että oppilaat tarvitsevat tukea nettilukutaitojensa kehittämiseen. Tukemalla ja tehostamalla esimerkiksi oppilaiden tiedonhaun ja kriittisen arvioinnin taitoja, voidaan varmistaa, että kaikki löytävät ja lukevat oppitunnin aikana relevantteja ja mahdollisimman luotettavia nettitekstejä. Tällöin aikaa ei tuhlaannu irrelevanttien tai epäluotettavien tekstien lukemiseen. Tämä on erityisen tärkeää varsinkin silloin, kun lukeminen on hidasta ja takkuaa. Lisäksi kun rajataan opeteltavien nettilukemisen osataitojen määrää tai harjoitellaan vaikkapa vain yhtä osataitoa kerrallaan, voidaan tukea tarkkaavuuden suuntaamista opeteltavaan asiaan. Oppimista voidaan tukea myös selvittämällä lisää, miten hyvin suoriutuvat oppilaat, joilla kuitenkin on oppimiseen liittyviä vaikeuksia, kompensoivat näitä vaikeuksiaan netissä tai vastaavasti tutkimalla tarkemmin, mistä niiden oppilaiden, joilla ei ole tunnistettuja oppimiseen liittyviä vaikeuksia, haasteet netissä johtuvat. Tätä kautta voidaan kehittää tukitoimia kaikille oppilaille ja varmistaa kaikille riittävät nettilukutaidot.

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ORIGINAL PAPERS

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LITERACY SKILLS AND ONLINE RESEARCH AND COMPREHENSION: STRUGGLING READERS FACE DIFFICULTIES ONLINE

by

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Literacy skills and online research and comprehension: struggling readers face difficulties online

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Abstract
The present study evaluated the extent to which literacy skills (reading fluency, written spelling, and reading comprehension), together with nonverbal reasoning, prior knowledge, and gender, are related to students' online research and comprehension (ORC) performance. The ORC skills of 426 sixth graders were measured using a Finnish adaptation of the Online Research and Comprehension Assessment. Results of a structural equation model showed that these ORC skills were divided into six highly correlated factors, and that they formed a common factor in ORC. Altogether, these predictor variables explained 57% of the variance in ORC. Reading comprehension, along with gender, was the strongest predictor for ORC performance. In addition, reading fluency and written spelling explained ORC variance over and above reading comprehension. These findings suggest that struggling readers probably face difficulties online.

Keywords Digital literacy · Online reading · Information literacy · Internet · Fluency · Comprehension · Struggling readers

Rapidly developing technology and the ubiquity of the Internet have changed people's reading practices, rendering the traditional view of literacy insufficient (Hartman, Morsink, & Zheng, 2010). Changes in the reading practices and skills needed in a modern society are already reflected in many nations' educational standards or curricula (Australian Curriculum, Assessment and Reporting Authority [ACARA], n.d..; The Finnish National Board of Education, 2016) as well as in international assessments (Fraillon, Ainley, Schulz, Friedman, & Gebhardt, 2013; Office for Economic Co-operation and Development [OECD], 2013a). Even in daily school life, utilizing the Internet for learning is a common practice: 95% of surveyed teachers in the United States reported doing research or searching for information online as

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a typical school assignment (Purcell et al., 2012). Because of the increased role of the Internet in school work and in other areas of life, educators should ensure that all students acquire sufficient skills to read and learn on the Internet.

Reading to learn from online information, often referred to as online research and comprehension (ORC), requires, in particular, skills and strategies for locating, evaluating, and synthesizing online information as well as for communicating one's learning to others (Leu, Kinzer, Coiro, Castek, & Henry, 2013b). Even though research has begun to identify the specific skills and strategies important when reading online (e.g., Brand-Gruwel, Wopereis, & Vermetten, 2005; Coiro & Dobler, 2007), there is still a need to better understand how traditional reading skills contribute to students' performance when they solve problems with online information. Understanding the consequences of poor literacy skills would help educators to design tasks and supports for students with varying literacy skills. As such, this study examined how different aspects of the literacy skills of reading, reading fluency, written spelling, and reading comprehension predict sixth graders' ORC performance. To achieve as thorough an understanding as possible on aspects related to ORC performance, we also included prior knowledge and nonverbal reasoning into our examination, as prior knowledge and inferential processes are seen as integral components of reading comprehension (McNamara & Magliano, 2009). Finally, because gender differences in literacy skills have been widely recognized (e.g., OECD, 2013a), gender was also included in our examination to clarify its role in ORC performance beyond reading ability.

Online research and comprehension

The present study is framed using an online research and comprehension framework (Leu et al., 2013b), which identifies five crucial component skills: (1) identifying an important question or a problem to solve, (2) locating information, (3) evaluating information critically, (4) synthesizing information, and (5) communicating information (see also Brand-Gruwel et al., 2005; Fraillon et al., 2013; International ICT Literacy Panel, 2002).

A reader begins online research by *identifying a question to answer or problem to solve.* In school or assessment contexts, the question or problem is often given to students. However, students are still required to build an understanding of the given task (Britt, Rouet, & Durik, 2018) that helps students to *locate relevant information* to solve the problem. Locating information requires the ability to form adequate search queries for search engines (Cho & Afflerbach, 2015) and to analyze search engine results (Rouet, Ros, Goumi, Macedo-Rouet, & Dinet, 2011). Without these skills, students are unable to use online information efficiently for their learning (Leu, Forzani, Burlingame, Kulikowich, Sedransk, Coiro, & Kennedy, 2013a).

Because a considerable amount of information on the Internet appears to be questionable (Britt & Gabrys, 2002) or commercially biased (Lewandowski, 2011), an ability to *critically evaluate online information* is essential. To make informed judgements of the quality of online information, readers need to evaluate the

author's expertise and the trustworthiness of online resources (Flanagin & Metzger, 2008; Pérez et al. 2018).

The fourth component skill—*synthesizing information*—refers to collecting ideas across resources and integrating these ideas into a versatile and coherent representation (Bråten, Britt, Strømsø, & Rouet, 2011; Cho & Afflerbach, 2017). A high quality synthesis also requires readers to compare and contrast information and different perspectives presented in multiple online resources (Cho & Afflerbach, 2015; Rouet, 2006). Finally, *communicating information* that one has learned requires good argumentation skills and the ability to address a specific audience. Presenting well justified arguments requires practice, especially when the information is controversial (Driver, Newton, & Osborne, 2000). Audience awareness may include components such as the greeting, addressing one's message to a reader, and using correct language (Lapp, Shea, & Wolsey, 2011), as well as properly concluding the writing (Berggren, 2014), all of which reflect a knowledge of communicative conventions.

A recent study (Kiili, Leu, Utriainen, Coiro, Kanniainen, Tolvanen, Lohvansuu, & Leppänen, 2018b) confirmed the basic structure of the four component skills (locate, evaluate, synthesize, and communicate) while also suggesting the introduction of additional complexity to the skill structure. First, evaluation of information was divided into two components: confirming the credibility of information, and questioning the credibility of information. It seems that questioning a source that is, for example, biased or lacking in expertise, is more difficult for students than confirming the credibility of the source with relevant expertise (Kiili, Leu, Marttunen, Hautala, & Leppänen, 2018a; Pérez et al. 2018). Second, synthesizing was divided into two separate components: identifying main ideas from a single online text, and synthesizing information across multiple online texts. This suggests that the process of building coherent intertextual relationships across multiple online texts requires somewhat different skills than building coherence within a single online text (Cho & Afflerbach, 2017).

Literacy skills: reading fluency, written spelling, and reading comprehension

Reading has been defined as consisting of two main skills: decoding and comprehension (Gough & Tunmer, 1986), which have been considered to be interconnected via reading fluency (LaBerge & Samuels, 1974). At the lower level of literacy skill development, the letter–sound decoding ability enables readers to process the graphic symbols and to identify single words by connecting the graphic symbol strings—that is, letters or their clusters—in spoken word representations (Kintsch & Rawson, 2005). In addition to decoding, written spelling requires the ability to phonologically recode spoken words into grapheme strings. It has also been suggested that this process further develops the word identification system via strengthening the words' orthographic representations (Perfetti & Stafura, 2014; Share, 2008). The development of the effectiveness and automatization of the basic decoding skill increases reading fluency, which is the ability to read the text accurately and rapidly

(Meyer & Felton, 1999; National Reading Panel, National Institute of Child Health & Human Development, 2000).

The development of fluency and effortless word recognition skills reduces the amount of attentional resources allocated for decoding and improves reading comprehension, which is a higher level of literacy skill (Fuchs, Fuchs, Hosp, & Jenkins, 2001; Tilstra, McMaster, Van den Broek, Kendeou, & Rapp, 2009). In reading comprehension, readers construct a text base model by combining and interrelating the word meanings of the text and by recognizing the wider topics within the entire text (Kintsch, 1998; Kintsch & Rawson, 2005). According to the lexical quality hypothesis (Perfetti, 2007), this kind of word-to-text integration requires a sufficient quality of word representations as well as the ability to efficiently retrieve word meanings from long-term memory (Perfetti & Stafura, 2014).

Finally, to build a deeper understanding of the text, readers need to construct a situational model by integrating the text base information with their prior knowledge (Kintsch, 1998). However, sometimes readers face difficulties with accurate and fluent word recognition, as well as with poor written spelling and decoding abilities, which may also lead to reading comprehension difficulties (Perfetti, 2007). These kinds of difficulties are defined as the lack of those skills that allow readers to construct meaning from the text (Fletcher, Lyon, Fuchs, & Barnes, 2007).

The relation of prior knowledge, reasoning, and gender to literacy skills

Prior topic knowledge plays an important role in comprehension of single texts (Cromley, Snyder-Hogan, & Luciw-Dubas, 2010; Tarchi, 2010), hypertexts (Amadieu, Tricot, & Mariné, 2009), and multiple texts (Bråten, Ferguson, Anmarkrud, & Strømsø, 2013). Prior topic knowledge may aid in navigation of networked texts (Amadieu et al., 2009; Salmerón, Cañas, Kintsch, & Fajardo, 2005); it may also support intertextual inferencing (Strømsø & Bråten, 2009) as well as the evaluation of information during online research (Forzani, 2016). However, Coiro (2011) found that even though prior topic knowledge played an important role in online research and comprehension performance of students with low online reading skills, it did not influence the performance of students with high online reading skills. Further, a recent study showed that even though prior topic knowledge was associated with knowledge acquisition after engaging with multiple web pages on a socio-scientific topic, it was not associated with multiple source integration (Andresen, Anmarkrud, & Bråten, 2018). These results suggest that prior knowledge is also an important factor in online research; however, further research is needed to better understand its role.

In addition to prior topic knowledge, theoretical models of reading specify inferential processes as integral for reading comprehension (Kendeou, McMaster, & Christ, 2016); as such, students with low verbal and nonverbal reasoning skills are more likely to have comprehension difficulties (Snowling, 2013). Nonverbal reasoning has been shown to have direct and indirect effects on reading comprehension (Swart et al., 2017); it has also been shown to support young at-risk readers' development of

comprehension skills (Peng et al., 2018). Online research may require reasoning skills additional to those required for the reading of a single text on paper. Readers need to make inferences about the usefulness of a web page with the incomplete information provided by search engines (Coiro & Dobler, 2007), intertextual inferences across online texts (Strømsø & Bråten, 2009), and source-content inferences to judge the quality of information (Britt et al., 2018). Reasoning skills are particularly needed when reading tasks—such as complex online research tasks—require critical thinking and problem solving (Adlof, Catts, & Lee, 2010).

Gender difference has also been an area of interest in literacy research. Girls have been shown to have an advantage in reading fluency and reading comprehension in several studies (Logan & Johnston, 2009; Torppa, Eklund, Sulkunen, Niemi, & Ahonen, 2018), including large-scale international studies, such as the Program for International Student Assessment (OECD, 2013b). Similar patterns have also been observed in some ORC studies (Forzani, 2016; Salmerón, García, & Vidal-Abarca, 2018).

The present study

In the current study, we set out to examine how literacy skills (reading fluency, written spelling, and reading comprehension), prior topic knowledge, nonverbal reasoning, and gender are related to students' ORC performance. We expected that reading comprehension, prior knowledge, nonverbal reasoning, and gender would independently contribute to explain the variance of ORC performance (Hypothesis 1). Studies using similar types of online reading tasks have found considerable overlap in skills needed in reading comprehension and online research tasks (Coiro, 2011; Hahnel, Goldhammer, Naumann, & Kröhne, 2016; Salmerón et al., 2018). In light of this research, we expected reading comprehension to be the strongest predictor of students' ORC performance. Of the other explanatory factors, prior topic knowledge has been shown to play an important role in comprehension of single and multiple texts (e.g., McNamara & Kintsch, 1996; Bråten et al., 2013). Therefore, we expected that prior topic knowledge would also independently contribute to ORC performance. Furthermore, an ORC task involving multiple online texts requires inferencing within and across texts that is not necessarily captured in multiple choice reading comprehension tests, which we also used in this study (Strømsø & Bråten, 2009). Therefore, we expected nonverbal reasoning to be another unique contributor to ORC performance over and above reading comprehension. We also included gender in our analyses, expecting to confirm previous findings that show that girls outperform boys in digital reading tasks (OECD, 2013b; Naumann & Sälzer, 2017; Salmerón et al., 2018). Finally, we were interested to test whether lower level literacy skills, reading fluency, and written spelling would affect ORC skills through reading comprehension or whether these skills would make their own contribution.

Method

Participants

The participants were 426 sixth-grade students (207 girls, 219 boys) aged from 12 to 13 years ($M = 12.34$, $SD = .32$) from eight elementary schools in Central Finland. Both large and average sized schools from urban and rural areas voluntarily participated. The data were collected during the fall semesters of 2014 and 2015. A statement from the Ethical Committee was obtained, and the participants' primary caregivers gave their written consent for participation in the study.

Measures and materials

Online research and comprehension

Students' ORC skills were measured with the Internet Reading Assessment (Internet Lukemisen Arviointi, or ILA test), which is a Finnish adaptation (see Kiili et al., 2018b) of the Online Research and Comprehension Assessment originally developed by Leu et al. (2013a). The test consists of a simulated closed Internet environment and tasks that measure four ORC skill areas: (1) locating information, (2) evaluating information, (3) synthesizing information, and (4) communicating information (see also Kiili et al., 2018b).

At the beginning of the test, students received an assignment by email from the principal of a fictitious school. In this email, the principal asked students to explore the health effects of energy drinks and to write a recommendation justifying whether the principal should allow the school to purchase an energy drink vending machine. During the test, students were guided through the tasks by two avatar students in an environment that simulated a social networking site with a chat message window.

Students were asked to read four online resources (two news web pages [OR1, OR4], an academic online resource [OR2], and a commercial online resource [OR3]) to form their final recommendation concerning the purchase of an energy drink vending machine. The students were also required to take notes while reading these online resources. Students were asked to locate two of these resources (OR2, OR4) by formulating a search query in a search engine. When they received the search engine result list, they were asked to distinguish the relevant online resource from the irrelevant ones. If a student failed in this locating task, the avatar student gave a link to the online resource in the social networking site. Two additional resources (OR1, OR3) were given to the students. Thus, even if a student was not able to receive credit for selecting the correct resource, they could still read and take notes from the relevant resources, thereby receiving credit for this part of the task.

Students were also asked to evaluate two of four online resources—an academic (OR2) and a commercial (OR3) online resource—with regard to the author's expertise in health issues as well as the overall credibility of the online resource itself. Instructions for the evaluation task were given by the avatar student in the chat

message window. After reading, taking notes, and evaluating the online resources, the students were asked to compose a summary text on the basis of what they had learned from these resources concerning the health effects of energy drinks. They were able to utilize their notes while writing the summary. Finally, the students were asked to compose an email to the principal, in which they justified their opinion concerning the purchase of the energy drink vending machine. [For a more detailed description of the ILA test and the content of the online resources, see Kiili et al. (2018a, 2018b). The scoring rubric for the measured skills can be found in the Appendix.]

The original assessment—the Online Research and Comprehension Assessment—was developed with acceptable levels of reliability and validity. Cronbach's α reliability coefficient for the energy drinks task was .83. Validity was established with a framework document approved by experts, 2 years of cognitive lab testing, and modifications based on a large scale pilot study (Leu et al., 2015).

To establish inter-rater reliability of coding, two independent coders, including the first and second author and trained research assistants, coded 20% of the responses for each of the 16 items. The kappa values for inter-rater reliability in locating information were 1.000. These varied in evaluation (four items) between .947 and .983, in identifying main ideas and synthesizing (six items) between .784 and 1.000, and in communication (two items) between .722 and .939. All disagreements were resolved by discussion. The remaining responses were scored by a single rater. Validation of the ILA was conducted through confirmatory factor analysis showing that the ILA assessment satisfactorily reflected the ORC framework (Kiili et al., 2018b).

Reading fluency

Fluency was measured using the three tests described below. A reading fluency factor (see the Data Analyses section) was formed on the basis of these tests. The McDonald's omega—a model based reliability—was .68 (cf. Zhang & Yuan, 2016).

The word identification test, a subtest of the standardized Finnish reading test battery ALLU (Lindeman, 1998), included 80 items, each consisting of a picture and four alternative written words. The students' task was to identify and connect correct picture–word pairs by drawing a line between a word and a picture. The score was the number of correctly connected pairs within the two minutes. The Kuder–Richardson reliability coefficient for the original test was .97 (Lindeman, 1998).

The word chain test (Holopainen, Kairaluoma, Nevala, Ahonen, & Aro, 2004) consisted of 25 chains of four words written without spaces between them. The students' task was to draw a line at the word boundaries. The score was the number of correctly separated words within the 90 s time limit. The test–retest reliability coefficient for the original test varied between .70 and .84.

The oral pseudoword text-reading test (Eklund, Torppa, Aro, Leppänen, & Lyytinen, 2014) consisted of 38 pseudowords (277 letters). These pseudowords were presented in the form of a short passage, which students were instructed to read aloud as quickly and accurately as possible. The reading performance of the students was audio recorded for consecutive scoring. The score was the number of correctly

read pseudowords divided by the time, in seconds, spent on reading. The inter-rater agreement for scoring the original test was .95 (Eklund et al., 2014).

Written spelling

Spelling accuracy was measured with a task in which students were asked to write 12 four syllable pseudowords from dictation (see Eklund et al., 2014). The recorded pseudowords were presented verbally to students twice, one at a time. The score was the number of correctly spelled items. Cronbach's alpha reliability coefficient was .49, and Revelle's omega reliability coefficient was .86.

Reading comprehension

Comprehension skills were tested using another subtest of the standardized Finnish reading test battery (Lindeman, 1998). In this subtest, students were asked to read an expository text of instructions for consumers and to respond to 12 multiple choice (four options) questions representing 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 when responding to the questions. The maximum score was 12 points. Cronbach's alpha reliability coefficient was .64, and Revelle's omega reliability coefficient was .86.

Nonverbal reasoning

Nonverbal reasoning ability was assessed with Raven's Standard Progressive Matrices test, which is a visuospatial task appropriate for children over 11 years of age (Raven, 1998). The test consists of 60 items, of which a shortened version was used containing 30 items (every second item from the larger test). Previous studies have shown that shortened versions produce an adequate estimate of nonverbal reasoning compared to the full version of Raven's Standard Progressive Matrices (see, e.g., Wytek, Opgenoorth, & Presslich, 1984). The total score was the number of items correctly responded to. In another large scale project with more than 800 sixth graders from the same area in Finland, the same shortened version was used with a Cronbach's alpha reliability coefficient of .81 (Kanerva et al., submitted for publication).

Prior knowledge

Prior knowledge (refering to prior topic knowledge) was tested with seven multiple choice (four options) questions on energy drinks and their health effects. The answer options included one correct option, two incorrect options, and a "don't know" option. One point was given for each correct selection, and zero points were given for selecting the other options. The Kuder–Richardson reliability coefficient for the total score was .89, and Revelle's omega reliability coefficient was .42.

Procedure

The data were collected in four separate researcher-led sessions: three 45 min group testing sessions and one five minute individual test session. During the first two group sessions, students completed the tests of literacy skills and nonverbal reasoning. In the third group session, the students completed the ILA test on laptops after answering prior knowledge questions. Students' performances were saved as log files and recorded with a screen capture program. During the assessment, the researchers provided technical assistance with the test application when needed. In the fourth session, the students completed the pseudoword text reading task in an individual test setting.

Data analyses

All analyses were conducted with Mplus version 7.3 and IBM SPSS Statistics 22. Since the pre-analysis of these data revealed some non-normality of the observed variables, and the ORC variables were categorical, the weighted least square (WLSMV) estimator was used in the structural equation model (SEM). WLSMV conducts the estimation with a diagonal weight matrix with robust standard errors and with a mean and variance adjusted χ^2 test statistic with a full weight matrix (Muthén & Muthén, 1998–2017). To ensure that the specified latent factors model adequately represented the data, the model fit was evaluated using multiple indices, including Chi square (χ^2), root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI), and weighted root mean square residual (WRMR). As an acceptable model fit, the following cutoff criteria were generally preferred: χ^2 test ($p > .05$), RMSEA $< .06$, TLI and CFI $\geq .95$, and WRMR $\leq .90$ (Hu & Bentler, 1999; Yu, 2002). Missing values were due, for example, to sickness absences. To estimate the model parameters, the incomplete cases were used in the analyses. WLSMV supposes that missingness is allowed to be a function of the observed covariates but not of the observed outcomes (Asparouhov & Muthén, 2010; Muthén & Muthén, 1998–2017). There were no missing values in the 15 observed variables of ORC skills, except 11.7% in NOTE2 and 7.7% in NOTE4 (Fig. 1). Neither were there any missing values in prior knowledge and gender. The amount of missing data varied between 0.5 and 1.6% in the reading fluency tests forming the factor. The amount of missing data was 2.6% in written spelling, 0.9% in reading comprehension, and 2.3% in nonverbal reasoning.

The six latent factors of ORC subskills (see Kiili et al., 2018b) were used in the SEM investigating literacy skills (reading fluency, written spelling, and reading comprehension), prior knowledge, nonverbal reasoning, and gender in relation to ORC. The first confirmatory factor analysis (CFA) model was formed on the basis of 15 observed variables. Since the six latent factors were highly correlated, another, more restrictive, CFA model with a common second order factor and six first order factors was evaluated against the first, less restrictive, CFA model. The comparison of these two nested models was implemented in Mplus with a DIFFTEST option.

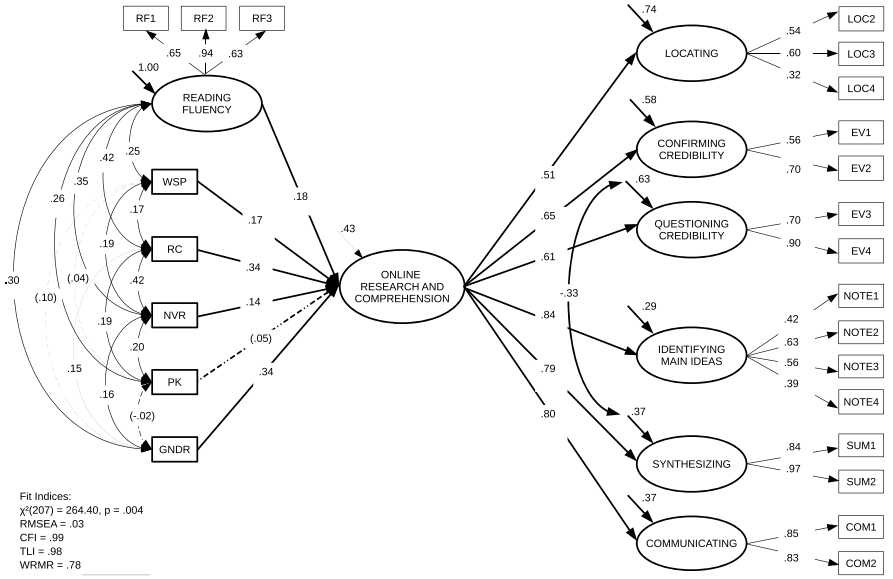

Fig. 1 SEM of literacy skills (reading fluency, written spelling [WSP], reading comprehension [RC]), nonverbal reasoning (NVR), prior knowledge (PK), and gender (GNDR) in relation to ORC skills. Notes. RF1 = word identification test, RF2 = word chain test, RF3 = oral pseudoword reading test. Measurement components are shown using thin lines and structural components are shown using bolded lines. Circles represent latent variables, and rectangles represent observed variables. All values are standardized, and all statistically significant ($p < .01$–$.001$) coefficients and unexplained variances are included in the figure. Nonsignificant relations are presented using brackets and dotted lines. The LOC1 observed variable did not load on the Locating factor (see Kiili et al., 2018b)

After endorsing the final measurement model, the following were included in the SEM: reading fluency as a latent factor; written spelling, reading comprehension, prior knowledge, and nonverbal reasoning as observed variables; and gender. The reading fluency factor was based on the three reading fluency tests described earlier. In the aforementioned SEM, the predictor variables were evaluated in relation to the common ORC factor. As an additional extension of the analyses, we also evaluated these same predictor variables in relation to the six ORC subskills.

Results

Descriptive statistics for literacy skills, prior knowledge, and nonverbal reasoning

Table 1 shows the descriptive statistics for the measured independent variables. Figure 1 shows the correlations between the independent variables.

Table 1 Descriptive statistics of literacy skills, prior knowledge, and nonverbal reasoning tests

Test	*M*	*SD*	Min.	Max.
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/second)[a]	0.70	0.21	0.19	1.36
Written spelling (max. 12 points)	8.17	2.09	2	12
Reading comprehension (max. 12 points)	6.91	2.53	1	12
Prior knowledge (max. 7 points)	4.48	1.46	0	7
Nonverbal reasoning (max. 30 points)	22.12	3.74	7	30

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

Dimensional structure of online research and comprehension skills

The results of the structural equation model are shown in Fig. 1. In this section, we present the measurement model for ORC skills. In the next section, we present the aspects that were predicted to explain students' performance in ORC.

The measurement model revealed six ORC factors. These were labelled (1) locating, (2) confirming credibility, (3) questioning credibility, (4) identifying main ideas, (5) synthesizing, and (6) communicating (see also Kiili et al., 2018b). In this CFA model, all parameter estimates were statistically significant ($p < .01$), and all fit indices indicated a good model fit (χ^2 (75) = 83.57, $p = .233$; RMSEA = .02; CFI = 1.00; TLI = 1.00; WRMR = .59). Since the factors were strongly correlated ($r = .29$–$.73$), a second order factor was set to capture the common variance across the six first order factors in another CFA model.

This common factor was named ORC. The second CFA model also demonstrated good fit to the data (χ^2 (84) = 108.77, $p = .036$; RMSEA = .03; CFI = .99; TLI = .99; WRMR = .72); however, the χ^2-difference test indicated that the less restricted model of the six first order factors would fit the data better ($\chi^{2\text{-diff}}$ (9) = 20.43, $p = .015$) than the model of the second order factor of ORC and the six first order factors. However, the modification indices suggested that the model fit would be better if the residuals of questioning credibility and synthesizing were allowed to correlate. This third CFA model fulfilled the criteria for a good model fit (χ^2 (83) = 89.50, $p = .294$; RMSEA = .01; CFI = 1.00; TLI = 1.00; WRMR = .64). In addition, the χ^2-difference test indicated that this more restricted CFA model would fit the data equally as well ($\chi^{2\text{-diff}}$ (8) = 7.18, $p = .517$) as the less restricted model of the six first order factors.

Based on these results, the third CFA model was considered as the final measurement model and was utilized as a part of the aforementioned final SEM (Fig. 1). In the SEM, the common ORC factor explained 26% of locating (.51; $p < .001$), 42% of confirming credibility (.65; $p < .001$), 37% of questioning credibility (.61; $p < .001$), 71% of identifying main ideas (.84; $p < .001$), 63% of synthesizing (.79; $p < .001$), and 63% of communicating (.80; $p < .001$). The negative correlation (.33; $p < .01$) between the residuals of questioning credibility and synthesizing indicated an inverse relation between the residuals.

Aspects explaining students' performance in online research and comprehension

In the next phase of the analysis, predictor variables were included in the SEM. Supporting Hypothesis 1, reading comprehension, nonverbal reasoning, and gender independently contributed to explain the variance of ORC performance: The regression coefficient of reading comprehension was .34 ($p < .01$), nonverbal reasoning was .14 ($p < .001$), and gender was .34 ($p < .001$). Contrary to our expectations, the relation between prior knowledge and ORC was nonsignificant. Furthermore, when examining lower level literacy skills in relation to the ORC performance, it was found that reading fluency and written spelling both independently contributed to ORC performance. The regression coefficient of reading fluency was .18 ($p < .01$) and written spelling was .17 ($p < .001$).

Altogether, predictor variables included in the SEM model explained 57% of the ORC variance. Therefore, 43% of the variance in the ORC factor remained unexplained. All the fit indices of the SEM, except the χ^2 test ($p = .004$), indicated a good model fit: CFI was .99, TLI was .98, RMSEA was .03, and WRMR was .78.

In order to understand the role of different literacy skills and other individual differences in students' performance in different areas of ORC, we conducted a differential examination with the six factor component model (Table 2). The results of this additional SEM indicated that reading comprehension was related to all other ORC subskills except locating information. Written spelling was related to locating, synthesizing, and communicating, whereas reading fluency was only related to communication. Further, gender was related to all other subskills except locating and confirming credibility, and nonverbal reasoning was related to identifying main

Table 2 Differential examination of the relations of literacy skills, prior knowledge, nonverbal reasoning, and gender to online research and comprehension subskills

	Locating	Confirming credibility	Questioning credibility	Identifying main ideas	Synthesizing	Communicating
	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)	B (SE)
Reading fluency	.18 (.09)	.07 (.08)	.13 (.08)	.12 (.08)	.13 (.07)	.18** (.06)
Written spelling	.24** (.07)	.09 (.06)	.07 (.06)	.11 (.06)	.15** (.05)	.11* (.05)
Reading comprehension	.14 (.07)	.38*** (.07)	.28*** (.07)	.32*** (.07)	.21*** (.06)	.22*** (.05)
Prior knowledge	.05 (.07)	.03 (.07)	.05 (.06)	.11 (.07)	.02 (.05)	-.01 (.05)
Nonverbal reasoning	.07 (.08)	.10 (.07)	.06 (.06)	.15* (.07)	.05 (.05)	.18** (.06)
Gender	.08 (.07)	.07 (.06)	.13* (.06)	.30*** (.07)	.34*** (.05)	.28*** (.05)
R^2	.22	.27	.22	.45	.32	.38

*$p < .05$; **$p < .01$; ***$p < .001$

ideas and communicating. All the fit indices of the SEM indicated a good model fit (χ^2 (169) = 206.22, p = .027; RMSEA = .02; CFI = .99; TLI = .99; WRMR = .63).

Discussion

The present study sought to understand the role that literacy skills (reading fluency, written spelling, and reading comprehension), prior knowledge, nonverbal reasoning, and gender play in sixth graders' ORC performance. Since the ORC subskills were highly correlated, the aforementioned variables were evaluated in relation to a common factor of ORC as well as in relation to ORC subskills.

Struggling readers face difficulties in online research and comprehension

In line with previous research (Coiro, 2011; Leu et al., 2015; Salmerón et al., 2018), reading comprehension, along with gender, was the strongest predictor for ORC performance, and it was also related to all ORC subskills except locating information. It might be that the current assessment, where students were given specific instructions for locating tasks, required more understanding of how search engines work than comprehension skills. In more open locating tasks, where readers need to comprehend the task assignment in order to formulate relevant search queries, reading comprehension may play a bigger role.

In addition, lower level literacy skills (reading fluency and written spelling) were unique predictors for the ORC performance. This contradicts the finding by Salmerón et al. (2018), who did not find an effect of word identification on the performance of an online reading task among secondary school students. It is worth noting that in the study by Salmerón et al. (2018), more emphasis was placed on the navigational component of online reading than in the present study. On the other hand, Hahnel, Goldhammer, Kröhne, and Naumann (2018) found that lower level reading skills, namely performance in a sentence verification task, made a unique contribution in addition to reading comprehension when students evaluated search engine web page results. As such, our results suggest that lower level reading skills in early adolescence can contribute to ORC performance. Slow reading makes it more difficult to read all the required materials in multiple online texts in a given time.

This is confirmed by the fact that—despite the unique contribution of reading fluency to the ORC common factor—fluency in the differential examination was primarily related to communication. The communication task required text based argumentation: that is, relying on reasoning based on the collection of information from multiple online texts, which presupposed the reading of whole web pages. Furthermore, written spelling was related to three subskills, with the strongest relationship to locating information. In our assessment environment, the search engine did not suggest correctly spelled search terms; as such, the relation we found might be stronger than it would be in authentic search environments, where search engines suggest corrections to misspellings.

The linear relationship of literacy skills to ORC performance suggests that those with below average reading fluency, written spelling, or reading comprehension are also very likely to have difficulties in ORC. Struggling readers seem to have difficulties especially in identifying main ideas and synthesizing and communicating information (see Fig. 1), which are essential skills for understanding the topic at hand. Lack of these skills may hinder their ability to learn from online information. When the direct relation of literacy skills to subskills was examined (Table 2), readers with poor reading comprehension skills also struggle with the evaluation of information.

Nonverbal reasoning and prior knowledge in online research and comprehension

In accordance with our expectations, nonverbal reasoning contributed independently to the variance of ORC performance. This is consistent with earlier findings suggesting a supportive role for nonverbal reasoning in reading comprehension (Swart et al., 2017; Peng et al., 2018). When examining the relation of nonverbal reasoning to ORC subskills, nonverbal reasoning was found to be related to identifying main ideas and communicating. In particular, communication tasks required reasoning skills because students were asked to form a recommendation and to justify it with reasoning that represented different perspectives covered in the online resources.

Even though prior knowledge has been found to play an important role in various reading contexts (e.g., McNamara & Kintsch, 1996; Bråten et al., 2013), it was not a significant predictor in the present study. One reason for this might be that all students had at least some general knowledge of energy drinks and health that helped them in the task, as the topic has been widely discussed in public and probably also in many homes. Notably, other ORC studies (Coiro, 2011; Leu et al., 2015) have found that prior knowledge does not play such an important role in students' ORC performance. On the other hand, Forzani (2016) found a positive but weak relation between prior knowledge and evaluation of information during online research. We want to point out that our finding might be related to how prior knowledge was measured in this study (see limitations). As such, one should be hesitant in drawing any conclusions about the role of prior knowledge on the basis of the current results.

Girls outperformed boys in online research and comprehension

Our results showing that girls outperformed boys in ORC are consistent with previous findings in digital reading contexts (Forzani, 2016; Naumann & Sälzer, 2017; Salmerón et al., 2018). Gender had a direct effect beyond indirect effects via literacy skills and other predictors. Therefore, there are other gender related differences that could explain why girls performed better than boys in the ORC task. Future research should explore the gender differences by evaluating, for example, the role of motivation for reading to learn from online information. Compelling evidence shows that girls show more positive motivation for traditional reading than boys (Wigfield & Guthrie, 1997) and that reading engagement seems to mediate their higher reading

scores (Chiu & McBride-Chang, 2006). This might be the case especially in Finland, where the gender difference in reading engagement is one of the widest among OECD countries (Brozo et al., 2014). Even though boys seem to have more positive attitudes towards computers (Meelissen & Drent, 2008), girls show better reading performance across different reading environments and tasks. Notably, gender differences were not found in locating information that might be perceived as relating to a more technology related activity.

Limitations and future research

The present study comes with several limitations that could be addressed in future research. First, students' ORC skills were measured with a performance based assessment that simulated online research in the closed, scaffolded information space. Students' literacy skills, prior knowledge, and nonverbal reasoning skills may play somewhat different roles in more complex, open Internet information spaces. Furthermore, assessing students' information locating skills in particular would benefit from several additional tasks that would better reveal students' search patterns (Kiili et al., 2018b). However, including all ORC subskills into one assessment requires compromising on the number of tasks. To complete the ILA assessment in its current form already requires students to invest a lot of cognitive effort.

Some of the other measures also have limitations. First, prior knowledge had somewhat low reliability. Second, prior knowledge was measured with only seven items that did not cover all perspectives on the topic presented in online resources. Furthermore, giving students the option to select "don't know" as an answer instead of the inclusion of an additional false option may have restricted the variability.

Finally, our study examined only a few potential sources of individual variation in online research and comprehension skills. 43% of the variance remained unexplained. One potential source could be metacognitive skills that are required particularly in complex reading tasks where readers need to compare and synthesize information from multiple online resources (Goldman, Braasch, Wiley, Graesser, & Brodowinska, 2012). Previous research has shown that good reading comprehension skills do not ensure students' success in integrating information from multiple texts (Stahl, Hynd, Britton, McNish, & Bosquet, 1996). Integrating information may also involve additional demands on working memory (Andresen et al., 2018; DeStefano & Levre, 2007). Additionally, students' attention and executive functions may contribute to their ORC performance, especially in synthesizing information. In traditional reading research, executive functions have been shown to be associated with reading comprehension (Follmer, 2018), and some evidence exists that inattention increases difficulties when working with online information (Desjarlais, 2013).

Theoretical and instructional implications

This study expands our theoretical knowledge of ORC and contributes to instruction. First, our findings suggested that, in future studies, students' performance in

ORC could be investigated as a single construct, since a large amount of the common variance in ORC subskills was captured by a latent structure. Thus, depending on the purpose of the study, the students' ORC skills could be examined by using either a general ORC construct or a more detailed component structure that is based on the theoretical model (Kiili et al., 2018b; Leu et al., 2013a, 2013b).

Because literacy skills partly overlap with ORC skills, instruction supporting students' literacy skills is important but not sufficient for educating skilled online readers. We believe that struggling readers would benefit from instruction that is relevant to both traditional reading and ORC. Online readers need effective comprehension strategies that they can apply in the context of both single and multiple texts (Cho & Afflerbach, 2015; Britt et al., 2018). As comprehension of multiple online resources goes beyond comprehension of a single online resource, students need instruction on accessing, selecting, evaluating, and using online resources that vary in their perspectives, interpretations, and genres (Britt et al., 2018).

Reading of multiple online texts might be overwhelming for many struggling readers. Because they need more time and effort for reading as compared to their classmates, struggling readers would benefit from guided practice in which they can integrate ideas from a limited numbers of texts, starting from two different texts. This would ensure more resources for practicing the specific skills needed for synthesizing, such as comparing and contrasting texts and forming ties between ideas originating from different online texts.

According to our model, all six component skills contribute to ORC performance, and all students, including struggling readers, need support to develop these skills. Students need to know how to form search terms, how to enter them into a search engine (Leu et al., 2013a), and how to examine who the author of an online resource is and why he or she has written the text (Cho & Afflerbach, 2015). Instruction focusing on effective locating and evaluation strategies would help struggling readers become more skilled in these areas. Being able to efficiently locate and evaluate online information would increase resources dedicated to making sense of relevant online texts. Because ORC requires novel approaches for teaching reading strategies and supporting students with special needs, increased attention should be paid to teacher professional development.

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Appendix

Scoring criteria for students' online research and comprehension performance by component skills

Sub-skill	Observed variables	Scores
Locating	Formulation of the first search query to locate OR2	0–2 p.
	Time spent locating OR2	0–4 p.
	Formulation of the second search query to locate OR4	0–2 p.
	Time spent locating OR4	0–4 p.
Confirming credibility	Evaluation of authors' expertise in the academic online resource (OR2)	0–3 p.
	Evaluation of credibility of information in the academic online resource (OR2)	0–3 p.
Questioning credibility	Evaluation of authors' expertise in the commercial online resource (OR3)	0–3 p.
	Evaluation of credibility of information in the commercial online resource (OR3)	0–3 p.
Identifying main ideas	Identifying main ideas from OR1: news page, reporting research results	0–2 p.
	Identifying main ideas from OR2: academic online resource, answering FAQs on energy drinks with a neutral tone	0–2 p.
	Identifying main ideas from OR3: commercial online resource, including only positive health effects of energy drinks in a press release	0–2 p.
	Identifying main ideas from OR4: news page, presenting an expert statement	0–2 p.
Synthesizing	Number of online resources used in the summary	0–3 p.
	Integration of ideas in the summary: coherence, coverage, and use of connectives	0–3 p.
Communicating	Quality of argumentation in the email: stance supported by online resources, number of reasons representing different perspectives	0–5 p.
	Communicative practices in the email: awareness of the audience, clear and polite way of expressing oneself	0–5 p.

OR1 = online resource 1; OR2 = online resource 2; OR3 = online resource 3; OR4 = online resource 4

For more detailed scoring criteria see Kiili et al. (2018b)

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II

ASSESSING READING AND ONLINE RESEARCH COMPREHENSION: DO DIFFICULTIES IN ATTENTION AND EXECUTIVE FUNCTION MATTER?

by

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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 inter-rater reliability in the ILA assessment were 1.000 for locating, and varied across the items: for evaluating, the Kappa values ranged from

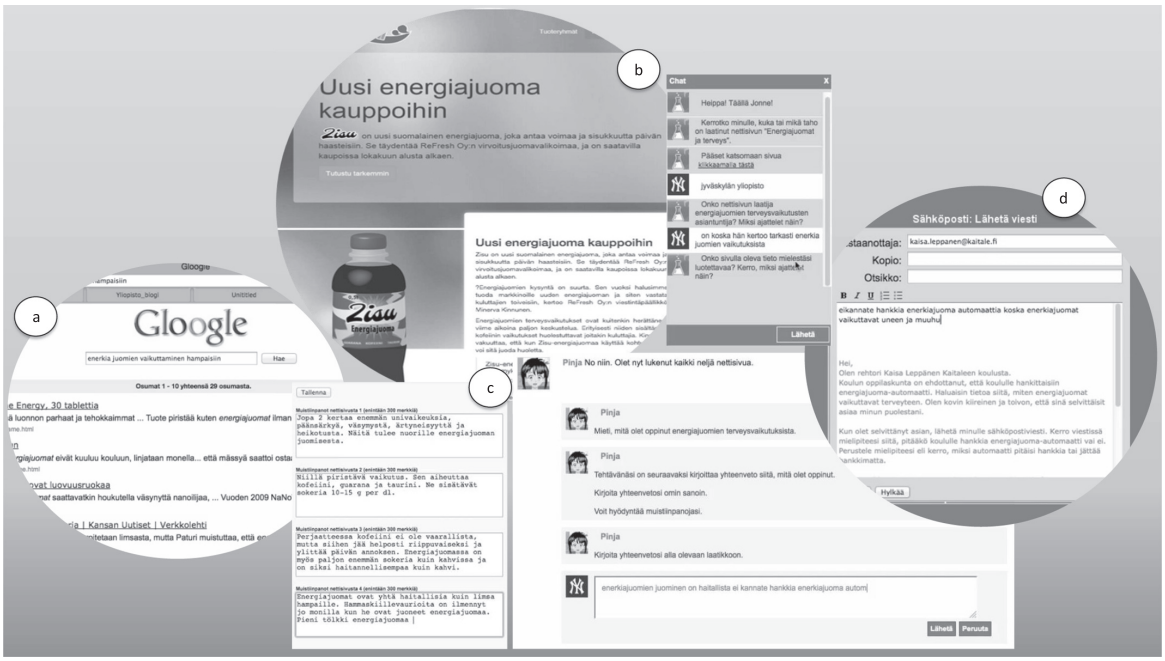

Fig. 1. Screen shots of a) the search engine for locating, b) the commercial online resource and the chat message window for evaluation, c) the note taking tool and the simulated social networking site for synthesis, and d) the mailbox for communication.

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\chi$2 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\chi$2 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

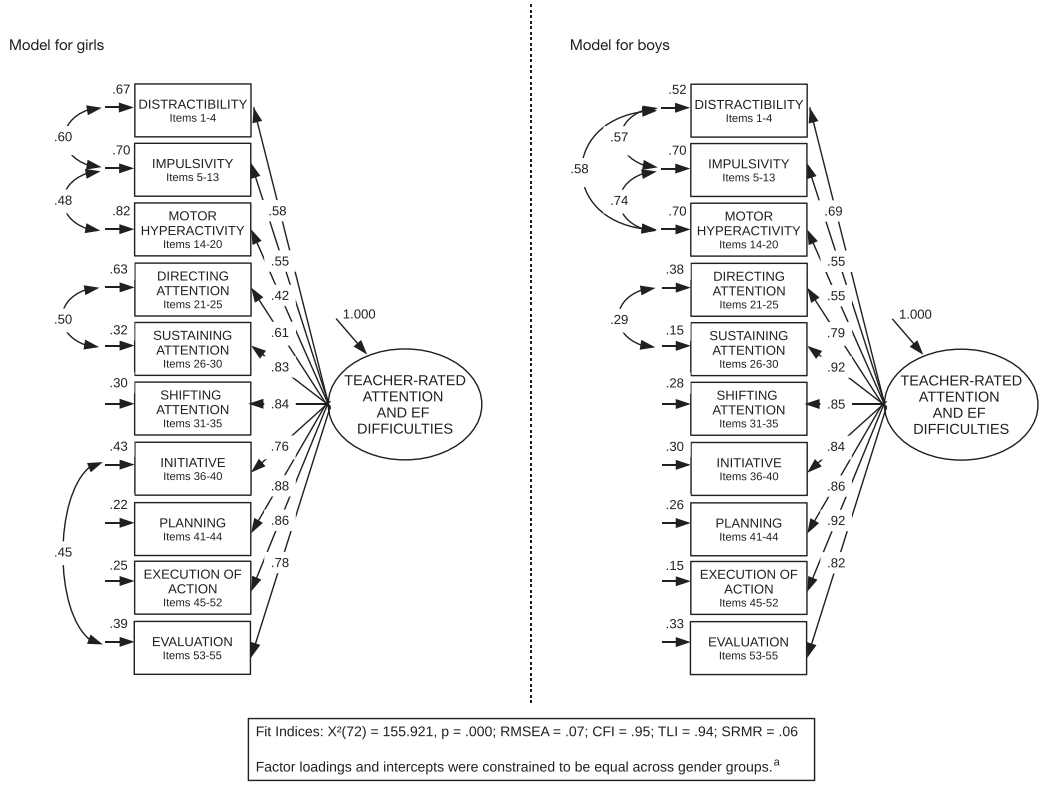

Fig. 2. Multigroup confirmatory factor analysis models (M3) showing the partial factorial invariance of teacher-rated difficulties in attention and executive function (EF) across gender. Notes: Only standardized and statistically significant ($p < .05$–$.001$) values are included in the figure. [a]All 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

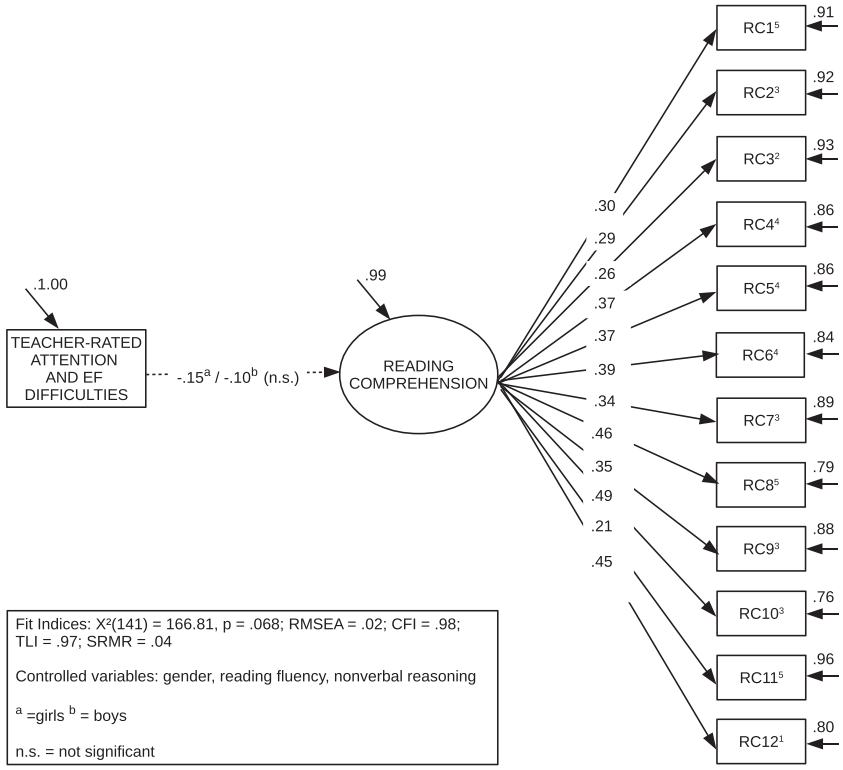

Fig. 3. Structural equation model (SEM1) of the association between students' difficulties in attention and executive function (EF) and their performance in reading comprehension (RC) assessed with a standardized multiple-choice task (ALLU), controlled for the main effect of gender (e.g., differences 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

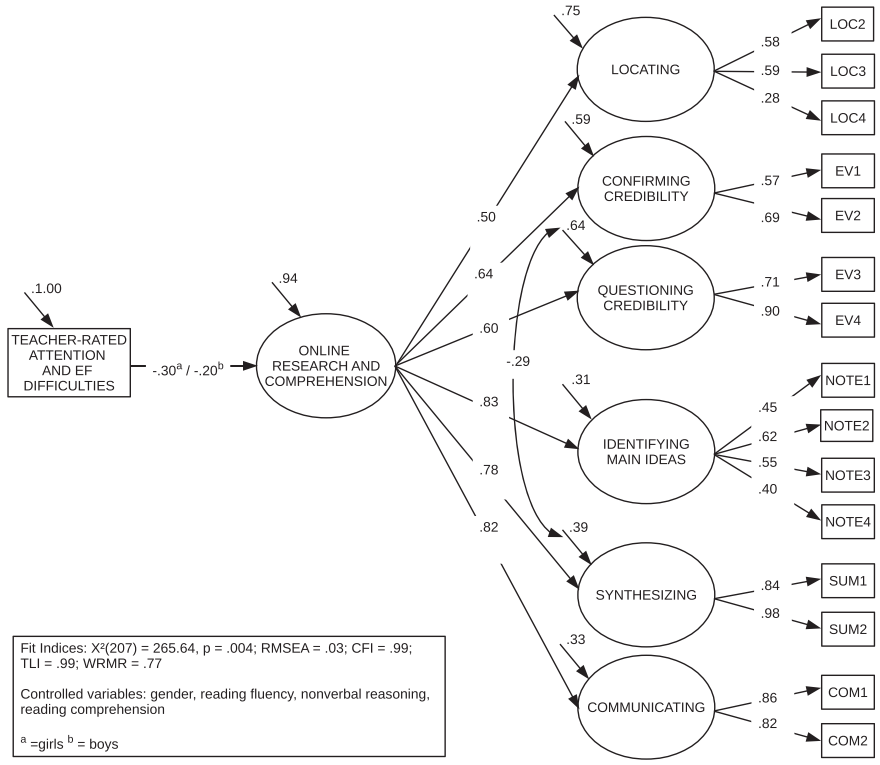

Fig. 4. Structural equation model (SEM2) of the association between students' difficulties in attention and executive function (EF) and their performance in online research and comprehension (ORC) assessed with a problem-solving task (ILA), controlled for the main effect of gender (e.g., differences 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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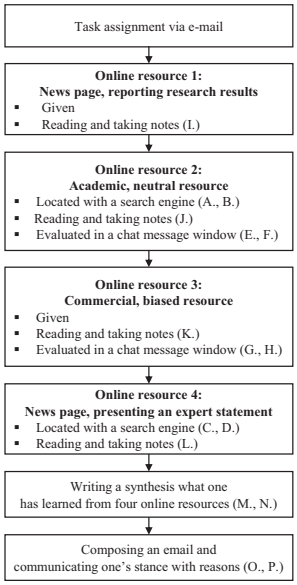
Appendix A. Flow of the ILA assessment and scoring criteria for students' online research and comprehension performance

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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III

ONLINE RESEARCH AND COMPREHENSION PERFORMANCE PROFILES AMONG SIXTH-GRADE STUDENTS, INCLUDING THOSE WITH READING DIFFICULTIES AND/OR ATTENTION AND EXECUTIVE FUNCTION DIFFICULTIES

by

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Online Research and Comprehension Performance Profiles Among Sixth-Grade Students, Including Those with Reading Difficulties and/or Attention and Executive Function Difficulties

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ABSTRACT

This study identified online research and comprehension (ORC) performance profiles of 436 sixth-grade students (206 girls) aged 12-13 years. We included learner groups with different learning-related difficulties and explored how students' reading habits were represented in various performance profiles. First, students' ORC performance was examined with a validated web-based assessment measuring their skills in locating, evaluating, synthesizing, and communicating information. Second, reading fluency and teacher-rated attention and executive function (EF) difficulty scores were used to form learner groups: (1) students with reading difficulties, (2) students with attention and EF difficulties, (3) students with comorbid difficulties in reading as well as attention and EF, and (4) students without these identified difficulties. Third, students' reading habits were assessed with a questionnaire asking how often they read different kinds of texts. Seven ORC performance profiles were identified. Most of the profiles related to the students' ORC performance level, except the profile of the average performers with low questioning credibility scores. Students with learning-related difficulties were more likely to belong to the lower performance profiles, and all top performers were students without identified difficulties. However, 25.7% of students with reading difficulties and 16.2% of students with attention and EF difficulties performed at average or good levels of ORC. Finally, the frequency of reading longer texts, such as books and blog posts, was more clearly associated with students' online reading performance than reading shorter texts, such as comics and online forum posts.

In the last two decades, remarkable progress has been made in understanding how readers learn from online information (Brand-Gruwel et al., 2009; Cho and Afflerbach, 2015; Coiro and Dobler, 2007; Leu et al., 2019). Research has illuminated the core skills of successful online reading but has also found substantial individual differences in these skills (Cho et al., 2018; Coiro et al., 2015; Fraillon et al., 2020; Leu et al., 2015; van Deursen, and van Diepen, 2013). To better understand the role of individual differences in acts of reading, we need to learn more about the nature and origin of these differences (Afflerbach, 2016). However, previous research has been limited in at least three respects.

First, researchers have examined how inter-individual differences, such as offline reading skills and prior knowledge, are associated with students' online reading performance (e.g., Coiro, 2011; Kanniainen et al.,

2019; Salmerón et al., 2018) but have rarely employed a person-centered approach that moves beyond the effects of single variables and characteristics to study multifaceted individual differences (Cromley, 2020). Second, most of the studies have focused on regular learners (Anmarkrud et al., 2018), except for a few studies concerning individuals with reading difficulties (Andresen et al., 2019a; Andresen et al., 2019b; Castek et al., 2011; Henry et al., 2012) or difficulties in attention and executive function (EF) (Caccia et al., 2019; Kanniainen et al., 2021). Moreover, to our knowledge, no previous studies have addressed learners' online research and comprehension (ORC) performance among individuals with comorbid—i.e., overlapping and co-occurring—difficulties in reading as well as attention and EF. Third, even though students seem to have different preferences for certain reading media and purposes (e.g., Jang et al., 2021; McKenna et al., 2012), the role of their reading habits has not been evaluated in association with their ORC performance.

Based on these three considerations, the present study aims to increase our understanding of the inter-individual differences in students' online reading performance by employing a person-centered approach—more precisely, latent profile analysis. In particular, we investigated how students with reading difficulties, students with teacher-rated attention and EF difficulties, students with comorbid difficulties in reading and attention and EF, and students without these difficulties are represented in different ORC performance profiles. To better understand learners' ORC performance, we also included students' reading habits, such as the frequency of reading books and online news, as an additional layer of investigation.

Online Research and Comprehension

In the present study, we build on the online research and comprehension (ORC) framework (Kinzer and Leu, 2017; Leu et al., 2019). This framework defines ORC as a self-directed, cyclical process that positions learners to construct texts and knowledge in web-based reading environments. During text and knowledge construction, learners employ the following component skills: (1) identifying questions, (2) locating information, (3) evaluating information, (4) synthesizing information, and (5) communicating information (Leu et al., 2019).

Learners begin by *identifying* task-relevant questions to direct their reading process and knowledge construction (Leu et al., 2019). In a school context, questions on a particular topic can be given by a teacher or generated together with a teacher and students (Kingsley and Tancock, 2014). *Locating* information by typing adequate search queries into a search engine and selecting relevant webpages from search results is another component of the process (Cho and Afflerbach, 2015; Coiro and Dobler, 2007). Successful online readers are able to adapt their search behavior according to the task features (Naumann, 2015) and, for instance, may use more time to formulate their search queries when the task demands increase (Walhout et al., 2017). Recently, eye-tracking research has successfully been applied to reveal learners' behaviors when using search engines to locate relevant information (for a review, see Lewandowski and Kammerer, 2020). For example, elementary-school students pay attention to titles, snippet texts, and even URL addresses of the search results, although some of the students may predominantly base their text selection only on the titles (Hautala et al., 2018).

Beyond the evaluation of the search results, learners should also critically *evaluate* the information processed during their knowledge construction (Leu et al., 2019). In terms of the credibility of information, skilled readers evaluate different content- and source-based features, such as the relevance and accuracy of the content, authors' expertise and intentions, and information type and date (Braasch et al., 2012, 2013; Macedo-Rouet et al., 2019; Stadtler and Bromme, 2014). Ideally, the evaluation of the content- and source-based features is reciprocal (Stadtler and Bromme, 2014), but many middle- and secondary-school students tend to rely on content features, such as readability and topical relevance, in their evaluations (Coiro et al., 2015; Macedo-Rouet et al., 2019). Even though adolescent readers may be able to name the authors behind the information (Coiro et al., 2015; Macedo-Rouet et al., 2013), they do not necessarily spontaneously evaluate the authors' competence or experience (Macedo-Rouet et al., 2019). In particular, when the information is, in a certain way, unreliable (e.g., published under commercial interests or in suspicious media), questioning the credibility of information seems to be challenging for readers (Kiili et al., 2018; Perez et al., 2018).

Furthermore, younger readers very rarely use their credibility evaluations when *synthesizing* information (Hämäläinen et al., 2020), although comparing and contrasting different viewpoints is essential for successful synthesis from multiple online texts (e.g., Cho and Afflerbach, 2015; Rouet, 2006). Although learners are expected to gather main ideas from multiple online texts (for reviews, see Barzilai et al., 2018; Primor and Katzir, 2018), both elementary-school students (Kiili et al., 2020) and secondary-school students (van Strien et al., 2014) may still base their knowledge construction on only one information resource or fail to fully integrate the contents from different online resources. However, specific instructions and prompts may help students in information integration (Barzilai et al., 2018). Especially, when the online information is controversial, students need practice in presenting well-justified arguments (Driver et al., 2000). In order to *communicate* information, learners are expected to have good argumentation skills to be able to address their justified, source-based position to a certain audience (Leu et al., 2019).

Reading Difficulties and Difficulties in Attention and Executive Function

Difficulties in reading and attention and EF are the two most common areas hindering learning (American Psychiatric Association, 2018) and, also, occur comorbidly—i.e., they overlap and co-occur in the same individual (Moll et al., 2020; Willcutt and Pennington, 2000). For instance, learners with difficulties in reading seem to have difficulties in attention and EF in 15–40% of cases (Shaywitz et al., 1995; Willcutt and Pennington, 2000; Willcutt et al., 2005). The prevalence of reading difficulties and difficulties in attention and EF suggests the need for a better understanding of how these learning-related problems are associated with student performance when reading to learn from online information.

Students with Reading Difficulties

Reading difficulties are defined as failure in accurate and fluent letter-sound decoding and word recognition skills (Gough and Tunmer, 1986; Lyon et al., 2003; Vellutino et al., 2004). The low accuracy and automaticity of decoding and word recognition are manifested in reduced reading fluency (Fuchs et al., 2001; LaBerge and Samuels, 1974; Perfetti and Stafura, 2014). At a higher level of reading, learners are expected to integrate word meanings and to recognize wider topics in order to construct a deeper understanding of the text (Kintsch, 1998). If learners' lower-level reading skills, such as decoding, word recognition, and reading fluency, are not sufficient, the problems may affect higher-level comprehension processes (Hulme et al., 2015; LaBerge and Samuels, 1974; Perfetti and Stafura, 2014).

Recent research on students' ORC skills is in line with this: difficulties in lower-level reading skills seem to reduce the level of online reading comprehension. For instance, Kanniainen et al. (2019) found that students' reading fluency level, measured using a factor consisting of word recognition and decoding of pseudowords, was associated with elementary-school students' online reading performance. Additionally, students' written spelling skills were associated with their ORC performance, and written spelling level also independently contributed to students' locating, synthesizing, and communicating skills (Kanniainen et al., 2019). Further, Macedo-Rouet et al. (2013) found that elementary-school students' word recognition skills were associated with how well students justified their information source selection, which seems to be a prerequisite for successful evaluation of information.

However, the role of lower-level reading skills seems to diminish among secondary-school students. For example, Salmerón et al. (2018) noticed that a word recognition task was associated with students' search selections on a search engine result page but not with their actual navigation processes and reading of online texts. Also, Hahnel et al. (2018) found that a word recognition task did not have a unique predictive power over reading comprehension on students' performance in the evaluation of information. Regardless of the grade level, it seems that reading comprehension is the strongest predictor of students' ORC performance and the components involved in successful performance (e.g., Coiro, 2011; Kanniainen et al., 2019; Salmerón et al., 2018).

Beyond this variable-centered view, there are only a few studies that have examined ORC among students with reading difficulties, and those were small case studies of three to four students (Castek et al., 2011; Henry et al., 2012). These studies have mainly concentrated on supportive technological and visual elements. For instance, web-based reading environments can provide comprehension support for learners with reading difficulties by providing non-textual elements, such as pictures and videos, making learners less dependent on their reading skills (Castek et al., 2011; Henry et al., 2012). However, based on a somewhat larger sample comparing 22 students with reading difficulties and 22 students without reading difficulties, it was shown that students with reading difficulties seem not to use these kinds of elements more often than students without reading difficulties (Andresen et al., 2019a).

Along with technological and visual elements, we know little about how students with reading difficulties are actually able to locate, evaluate, synthesize, and communicate information and what kinds of ORC performance profiles they represent. It is noteworthy that some students may even be able to use some compensatory mechanisms to cope with their reading difficulties online. For example, Andresen et al. (2019b) found that in a group of four dyslexic students, one student with serious reading difficulties managed to increase his or her knowledge substantially by compensating for reading deficiencies by dedicating time to the task.

Students with Attention and Executive Function Difficulties

Difficulties in students' attentional processes and EF are defined as failure to focus, sustain, and shift attention (Mirsky et al., 1999), as well as failure to inhibit, for example, external distractions and update working memory contents (Friedman and Miyake, 2017; Miyake et al., 2000). Further, at a higher level of EF, learners may face difficulties when expected to be able to plan and monitor their actions (for reviews, see Diamond, 2013; Friedman and Miyake, 2017). Thus, difficulties in attentional processes (e.g., Cain and Bignell, 2014; Miller et al., 2013) and EF (for reviews, see Butterfuss and Kendeou, 2018; Follmer, 2018) may interfere with learners' reading comprehension by impeding their ability to build mental representations.

Learners' ability to build mental representations may be even more crucial online. For example, Caccia

et al. (2019) found that both students' self-reported and measured attention and EF difficulties—more specifically concentration difficulties—were associated with their online reading performance. Further, in a study by Kanniainen et al. (2021), teacher-reported difficulties in students' attentional processes, execution of actions, and inhibition were associated with their ORC performance in a simulated Internet environment. In web-based reading environments, students are required to go beyond processing a single linear text and shift their attention between multiple texts and different ORC processes. Thus, web-based reading environments seem to set additional requirements for learners to monitor and regulate their actions (Cho et al., 2017; Coiro and Dobler, 2007).

Students with Comorbid Difficulties

The above-defined reading difficulties and difficulties in attention and EF can show comorbidity among the same individuals (e.g., Moll et al., 2020; Willcutt and Pennington, 2000). Learners with comorbid difficulties often face more academic difficulties than learners with either deficiency alone (e.g., Willcutt et al., 2007). As shown above, students with low literacy skills or difficulties in attention and EF may struggle online. Although no previous studies have addressed ORC performance among learners with comorbid difficulties, it is highly likely that reading in complex web-based environments is cognitively overloading, especially for learners with both reading difficulties and difficulties in attention and EF. Deep-level text processing is necessary for reading to learn from multiple texts, as readers are required to integrate information and formulate conclusions across these texts (Dinsmore and Alexander, 2016; List and Alexander, 2017). Particularly for students with comorbid difficulties, this kind of deep-level text processing may take a great deal of time and effort and require instructional support.

Students' Reading Habits

To build a deep-level, coherent understanding of a text, readers need to elaborate main ideas in a text by integrating those ideas with their prior knowledge (Kintsch, 1998). However, younger readers may not necessarily be skilled enough to draw on their prior knowledge to establish coherence, especially if they also have difficulties related to comprehension (e.g., Brandão and Oakhill, 2005; Cain et al., 2001). Reading comprehension and knowledge seem to have a reciprocal relationship in which knowledge supports comprehension but comprehension also seems to support the use of knowledge as well as the building of new knowledge (for a review, see Cervetti and Wright, 2020). Thus, knowledge can also be regarded as a product of reading comprehension beyond its role as a predictor. Students who read in their free time seem to develop not only stronger reading fluency and comprehension skills but also a larger knowledge base than students who read less (for reviews, see Mol and Bus, 2011; Schiefele et al., 2012). Hence, it is important to include learners' reading habits in the examination of their ORC performance.

Book-reading seems to be the strongest predictor of successful reading comprehension, whereas reading other materials, such as newspapers, magazines, and comics, has only minor or no effects (Pfost et al., 2013; Spear-Swerling et al., 2010; Torppa et al., 2020). In regard to learners' digital reading habits, it seems that digital text consumption may even have negative associations with comprehension. For example, Pfost et al. (2013) and Torppa et al. (2020) found that the reading frequency of digital texts, such as emails, instant messages, and forum posts, was negatively associated with students' comprehension. However, learners' digital reading habits should not be seen narrowly, only from the perspective of social online engagement. Namely, Lupo et al. (2017) found that students' positive attitudes toward reading academic digital texts, such as ebooks and online news for a class, correlated positively with reading comprehension, but attitudes toward free time reading of digital texts, such as emails and instant messages, did not.

Further, Naumann (2015) found a negative relation between social online engagement and students' navigation behavior—i.e., the number of students' visits and revisits to task-relevant pages, but a positive relation between students' navigation and information engagement, such as reading online news and searching for information on the Internet. Though most students are used to utilizing digital media, there are students who prefer more print media (Jang et al., 2021; McKenna et al., 2012). However, more research is needed, particularly an examination of how students' reading habits are associated with their performance when reading to learn from online information.

The Present Study

We set out to examine learners' various profiles of online research and comprehension performance by using a person-centered approach, more specifically latent profile analysis. By including different learner groups, this study aims to increase our understanding of how students' reading difficulties and/or teacher-rated difficulties in attention and EF are associated with their ORC performance. Reading habits may also play an important role when elementary-school students read in web-based environments; thus, we also examine learners' reading habits in relation to their ORC performance. Specifically, we sought to answer the following three research questions:

1. What kinds of online research and comprehension performance profiles can be identified among sixth-grade students?

2. How are different learner groups (students with reading difficulties, students with attention and EF difficulties, students with comorbid difficulties in reading and attention and EF, and students without these identified difficulties) represented in various online research and comprehension performance profiles?
3. How do students' reading habits vary across different online research and comprehension performance profiles?

In this study, we used latent profile analysis, which is, like other person-centered approaches, typically conducted in an exploratory manner (Hoijtink, 2001; Meyer and Morin, 2016). Thus, we do not give an a priori hypothesis for the number or nature of the online research and comprehension performance profiles. Further, we do not give an a priori hypothesis for how the different learner groups or students' reading habits are represented in these data-driven profiles.

Method

Sample and Procedure

The participants were 436 students (M age = 12.34, SD = 0.33; 47% females) attending the sixth grade of basic elementary education in Finland during the years 2014–2016. Based on the students' reading fluency and teacher-rated attention and EF difficulty scores, they were divided into learner groups: (1) students with reading difficulties (n = 39), (2) students with attention and EF difficulties (n = 37), (3) students with comorbid difficulties in reading as well as attention and EF (n = 17), and (4) students without these identified difficulties (n = 343). The identification criteria are presented later in the Learner Groups section.

Of these 436 students, 426 were recruited from 24 intact classes representing eight Finnish elementary schools, both suburban and rural. We contacted (by email or phone) the school principals, who then forwarded our recruitment request to classroom teachers. Thirteen students were excluded from the analysis because of missing data essential for assigning students to learner groups. Based on the prevalence of the reading and attention and EF difficulties (American Psychiatric Association, 2018), students with these difficulties were underrepresented among the 426 students. Thus, an additional 23 students with reading difficulties and/or teacher-rated difficulties in attention and EF were recruited by contacting special education teachers and psychologists because we were especially interested in how students with these kinds of difficulties performed online. These students were recruited from another seven elementary schools representing basic elementary education in Finland. The population of the first eight schools was similar to that of the latter seven. The special education teachers and psychologists contacted the students' guardians to ask for permission for the students to participate.

All 436 students participated voluntarily and were taught in mainstream classrooms. Most special educational services are provided in schools for free and a formal diagnosis is not needed for students to receive these services (Björn et al., 2016). The most common form of special educational services is part-time special education given by a special education teacher (Pulkkinen et al., 2020), in which students are studying in mainstream classrooms and receive support, for example, for reading and spelling a few hours per week from a special education teacher (Holopainen et al., 2018). This support is often put into practice in a small group (3–4 students at the same time) or individually, if the difficulties are more severe or if the student has multiple learning-related difficulties at the same time (Holopainen et al., 2018). All participating 436 students followed the Finnish National Curriculum (The Finnish National Board of Education, 2004). In this version of the curriculum, the ORC component skills mainly appeared in the subject of Finnish language and literature. For instance, the Finnish language and literature section of the curriculum identifies the importance of locating information, critically evaluating it, and using multiple information resources in knowledge construction or synthesis.

The Ethical Committee of the University of Jyväskylä gave their approval, and the guardians signed a written consent form for their children's participation. Most parents of participating students had at least an upper-secondary education (93% of mothers and 88% of fathers). This is close to the Finnish national average, which is 88.3% of people aged 25–54 with at least an upper-secondary education (Eurostat, 2013). Our sample was also relatively homogeneous in regard to students' access to the Internet and email. Specifically, 97% of students had internet access at home, and 90% of students had an email address.

The data were collected at schools during three regular 45-minute class periods. In the first two sessions, students completed paper-and-pencil tests and a questionnaire concerning their reading habits. In the last session, the students completed an online research and comprehension task with laptops at their own pace. If needed, students were allowed to use their 15-minute recess to complete the task.

Measures

Online Research and Comprehension

We measured students' online research and comprehension skills using a Finnish online research and comprehension assessment (Kiili et al., 2018). This assessment was modified from a previous one called ORCA, which was

developed in the United States with good levels of validity and reliability (Leu et al., 2015). The assessment simulated an internet environment and consisted of tasks that measured four ORC components: (1) locating information, (2) evaluating information, (3) synthesizing information, and (4) communicating information. Neither the original assessment, ORCA, nor the Finnish assessment included a task measuring the component of identifying important questions. Thus, the results should be considered as representing directed inquiry, as opposed to independent inquiry.

The assessment began with an email containing a common task assignment, which was sent by a fictitious school principal. The principal instructed students to explore the health effects of energy drinks and to write a justified recommendation on whether or not an energy drink vending machine should be purchased for the school. In the assessment, students were prompted through the tasks by two avatar students. The avatars prompted students via a simulated social networking site and a chat message window. 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]) during the task to form their recommendation. Next, we will describe the subtasks by the component skills that they measured.

In the *locating* component, students formulated a search query in a search engine to locate two of the online resources (OR2, OR4). The avatar prompted students by giving the following instructions: "My friend gave me a tip about a webpage of a certain university presenting information related to energy drinks. Please find this webpage [OR2]"; "I have heard my friends talking about the health effects of energy drinks on teeth. Next, please find a webpage about these effects [OR4]." After the search query, students received the search engine result page and were asked to distinguish the relevant online resource from the irrelevant ones. If a student failed in this task, the avatar gave the right link to the correct online resource. Thus, students were still able to read the correct resource and receive credits in the next parts of the task. In the *evaluation* component, students evaluated two online resources (OR2, OR3) by answering three questions presented by the avatar: (1) "Who is the author of the webpage?"; (2) "Is the author an expert on health issues related to energy drinks? Why do you think so?"; (3) "Is the information provided on the webpage reliable? Why do you think so?"

In the *synthesizing* component, students took notes from all four online resources with a notetaking tool. The avatar prompted students to use their own words. After reading all four resources, students wrote a summary of what they had learned about the health effects of energy drinks by synthesizing information across the resources. The notes were available when students wrote their summaries. In the *communication* component, students responded to the principal's email by composing a justified recommendation regarding whether or not the principal should purchase the energy drink vending machine for the school.

Figure 1 presents a flowchart of the ORC assessment and scoring criteria for students' performance in the aforementioned components. Screenshots of the stimulus materials are also presented in Figure 1, and descriptive statistics are presented in Table 1. The Kappa values for inter-rater reliability were 1.00 for locating and ranged from .95 to .98 for evaluating, from .78 to 1.00 for synthesizing, and from .72 to .94 for communicating. McDonald's omega reliability coefficient for the total score was .88.

Validation of the factor structure of the Finnish assessment was performed via confirmatory factor analysis. The results reflected the original ORC model (Kiili et al., 2018). The standardized factor scores for each component skill, based on previous work (Kiili et al., 2018), were used in the analyses, and we present the factor structure in the data analysis section.

Reading Fluency

We measured students' reading fluency with three tests: a time-limited word recognition test (Lindeman, 1998), a time-limited word chain test (Holopainen et al., 2004), and an oral pseudoword-reading test (Eklund et al., 2015). Descriptive statistics for reading fluency tests are presented in Table 1. McDonald's omega reliability coefficient for these three tests was .79.

In the group-administered word recognition test (Lindeman, 1998), we instructed students to identify and connect the correct picture–word pairs by drawing a line between a word and a picture. This test included 80 items, and each item consisted of a picture and four alternative written words. The score was the number of correctly connected pairs within the time limit of two minutes.

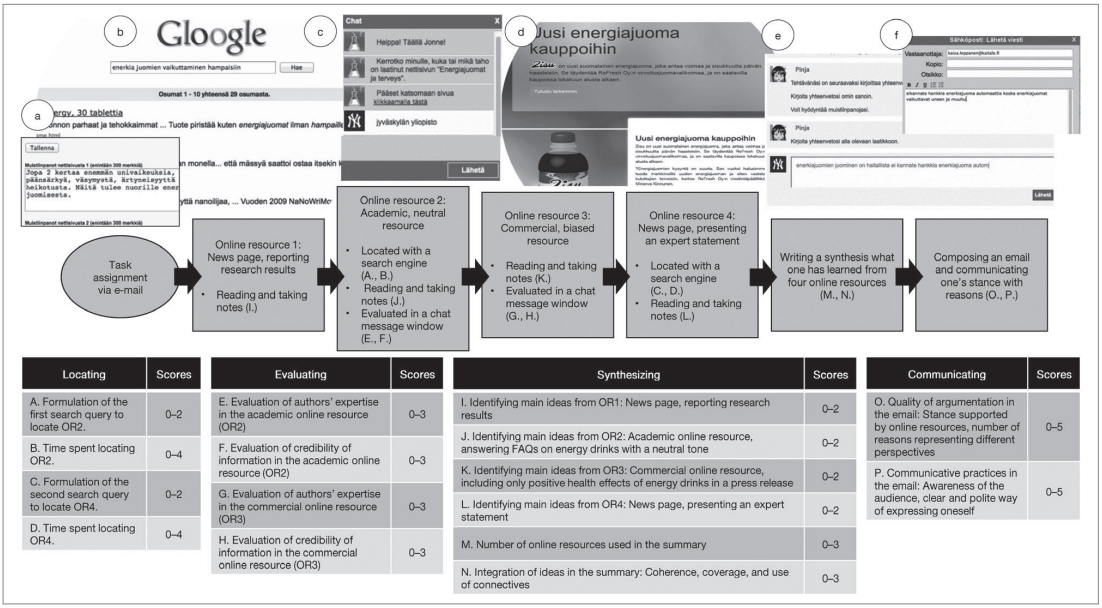
In the group-administered word chain test (Holopainen et al., 2004), we instructed the students to draw a line at the word boundaries. This test consisted of 25 word chains of four words written without spaces between them. The score was the number of correctly separated words within the 90-second time limit.

In the individually administered oral pseudoword-reading test (Eklund et al., 2015), we instructed students to read aloud as quickly and accurately as possible a short passage of 38 pseudowords (277 letters). Students' reading performance was audio-recorded for scoring, and the score was the number of correctly read pseudowords divided by the time, in seconds, spent on reading.

Teacher-Rated Attention and Executive Function Difficulties

To assess students' attention and EF difficulties, we used the Attention and Executive Function Rating Inventory

FIGURE 1
Screenshots and a Flowchart of the Online Research and Comprehension Assessment, Together with the Scoring Criteria for Students' Performance



Locating	Scores
A. Formulation of the first search query to locate OR2.	0–2
B. Time spent locating OR2.	0–4
C. Formulation of the second search query to locate OR4.	0–2
D. Time spent locating OR4.	0–4

Evaluating	Scores
E. Evaluation of authors' expertise in the academic online resource (OR2)	0–3
F. Evaluation of credibility of information in the academic online resource (OR2)	0–3
G. Evaluation of authors' expertise in the commercial online resource (OR3)	0–3
H. Evaluation of credibility of information in the commercial online resource (OR3)	0–3

Synthesizing	Scores
I. Identifying main ideas from OR1: News page, reporting research results	0–2
J. Identifying main ideas from OR2: Academic online resource, answering FAQs on energy drinks with a neutral tone	0–2
K. Identifying main ideas from OR3: Commercial online resource, including only positive health effects of energy drinks in a press release	0–2
L. Identifying main ideas from OR4: News page, presenting an expert statement	0–2
M. Number of online resources used in the summary	0–3
N. Integration of ideas in the summary: Coherence, coverage, and use of connectives	0–3

Communicating	Scores
O. Quality of argumentation in the email: Stance supported by online resources, number of reasons representing different perspectives	0–5
P. Communicative practices in the email: Awareness of the audience, clear and polite way of expressing oneself	0–5

Notes. (a) The notetaking tool, (b) the search engine, (c) the chat message window, (d) the commercial online resource (OR3) as an example of online resources, (e) the simulated social networking site, and (f) the mailbox. OR1 = online resource 1; OR2 = online resource 2; OR3 = online resource 3; OR4 = online resource 4. More detailed scoring criteria published by Kiili et al. (2018) are available upon request from the first author. One of the observed variables of locating (A.) did not load on the locating factor, and thus, was omitted from the analyses in the validation of the assessment (see Kiili et al., 2018).

(ATTEX; Klenberg et al., 2010b). With the inventory, teachers ($N = 24$) evaluated all their student's difficulties in attention and EF in school-related situations. Teachers were asked to rate students' difficulties with 55 items under ten scales. Each item had a three-point response scale (0 = not a problem; 1 = sometimes a problem; 2 = often a problem). An example item from each scale and the descriptive statistics are presented in Table 1. The ATTEX inventory is available in English as an appendix in Klenberg et al. (2010b). The ATTEX inventory has shown good criterion validity ($r = .76–.95$; Klenberg et al., 2010b) with the ADHD Rating Scale–IV: School Version (DuPaul et al., 1998). In the present study, McDonald's omega reliability coefficient was .94.

Learner Groups

As mentioned earlier, students do not need a formal diagnosis to receive special educational services in Finnish educational system (Björn et al., 2016). Thus, in the school context teachers and parents together with students assess the need for support by themselves (Holopainen et al., 2018). In the research context, researcher measures, such as composite scores and rating scales with different kinds of cut-offs are frequently used. For instance, the lowest 10th percentile on a reading composite score, including accuracy and fluency measures, is often considered as a cut-off point for dyslexia among Finnish children (Jyväskylä Longitudinal Study of Dyslexia [JLD]; see Eklund et al., 2015; Torppa et al., 2010), but also in other languages as well (for a review, see Snowling and Melby-Lervåg, 2016; Pennington et al., 2012).

Hence, students' reading fluency was measured by a single reading fluency factor based on performance in the three reading tests described above (under Reading Fluency). The reading fluency factor was obtained using principal axis factoring (PROMAX rotation; an eigenvalue of 1 as a criterion). Students whose reading fluency score was below the 10th percentile were included in the group of students with reading difficulties ($n = 39$; 33% females). The 10th percentile cut-off value was formed based on the original group of 426 participants, and the 23 supplementary participants were assigned to the groups based on this cut-off. For the supplementary participants, we calculated the factor scores by adding one student at a time to the main data, and then running the factor analysis to get the factor score for each of these students. This was done as a preliminary step of the analysis

TABLE 1
Descriptive Statistics of Online Research and Comprehension, Reading Fluency, and Teacher-Rated Attention and Executive Function Difficulties

Online Research and Comprehension	*M*	*SD*	*Min.*	*Max.*
1) Locating Information (max. 10 points)	4.73	2.14	0.00	10.00
2) Evaluating Information (max. 12 points)	5.76	3.03	0.00	12.00
3) Synthesizing Information (max. 14 points)	6.83	2.90	0.00	14.00
4) Communicating Information (max. 10 points)	4.31	2.41	0.00	10.00
Reading Fluency	***M***	***SD***	***Min.***	***Max.***
1) Word Recognition Test (max. 80 points)	48.42	9.34	21.00	80.00
2) Word Chain Test (max. 100 points)	42.81	14.50	11.00	85.00
3) Pseudoword-Reading Test (correctly read words/seconds)	0.70	0.21	0.19	1.36
Teacher-Rated Attention and Executive Function Difficulties	***M***	***SD***	***Min.***	***Max.***
1) Distractibility (q1–4; max. 8 points): 'Activities are interrupted by even the smallest external distracter' (q1)	1.08	1.66	0.00	8.00
2) Impulsivity (q5–q13; max. 18 points): 'Is clearly impatient' (q5)	1.77	3.50	0.00	18.00
3) Motor Hyperactivity (q14–q20; max. 14 points): 'Constantly needs manual activities' (q14)	0.80	1.99	0.00	14.00
4) Directing Attention (q21–q25; max. 10 points): 'Has difficulties focusing attention on instructions given to the whole group' (q21)	1.33	2.08	0.00	10.00
5) Sustaining Attention (q26–q31; max. 12 points): 'Has difficulties completing tasks' (q26)	1.16	2.22	0.00	12.00
6) Shifting Attention (q32–q35; max. 8 points): 'Has difficulties noting two things at the same time' (q32)	0.73	1.58	0.00	8.00
7) Initiative (q36–q40; max. 10 points): 'Is not able to start on tasks without extra supervision' (q36)	1.14	2.02	0.00	10.00
8) Planning (q41–q44; max. 8 points): 'Starts working on tasks without planning' (q41)	0.74	1.56	0.00	8.00
9) Execution of Action (q45–q52; max. 16 points): 'Needs additional. individual supervision to accomplish tasks' (q45)	1.60	2.60	0.00	14.00
10) Evaluation (q53–q55; max. 6 points): 'Is not able to foresee consequences of own actions' (q53)	0.52	1.13	0.00	6.00

to prevent overrepresentation of this supplementary sample in the factor score estimation.

Next, we calculated the scores for students' teacher-rated attention and EF difficulties. To decide whether students belonged to the group of students with attention and EF difficulties (n = 37; 19% females), we used the cut-off scores from the ATTEX manual (Klenberg et al., 2010a): 36 points for boys and 20 points for girls. If a student had difficulties in both areas, they belonged to the group of students with comorbid difficulties in reading and attention and EF (n = 17; 24% females). The remaining students belonged to the group of learners without identified difficulties (n = 343; 53% females).

Reading Habits

We measured students' reading habits via a self-report questionnaire including eight items. The first four items measured print reading frequency: students' frequency of reading (a) books (e.g., novels, nonfiction), (b) newspapers (an example of the Finnish newspaper), (c) magazines (examples of Finnish magazines targeted to adolescents), and (d) comics. The last four items measured digital reading frequency: students' frequency of reading (a) ebooks, (b) online newspapers (examples of Finnish online newspapers), (c) websites on various topics (e.g., interests, hobbies, sports), (d) blog posts, and (e) forums (e.g., discussions of games, artists, hobbies). Ratings were given on a 5-point Likert scale [1 = hardly ever; 2 = rarely (1–2 times per month); 3 = 1–2 times per week; 4 = almost every day; 5 = every day]. McDonald's omega reliability coefficient was .62. Presumably, the somewhat low omega was due to the omega's assumption of unidimensionality (see, e.g., Savalei et al., 2019). Students seem to prefer different kinds of media and purposes (see also Jang et al., 2021); thus, we used these variables at the item level. Descriptive statistics for reading habits are presented in Table 2.

TABLE 2
Descriptive Statistics of Reading Habits

Print Reading Habits	*M*	*SD*
1) Books	2.87	1.20
2) Newspapers	1.97	1.01
3) Magazines	1.82	0.90
4) Comics	2.76	1.30
Digital Reading Habits	***M***	***SD***
1) Ebooks	1.08	0.39
2) Online Newspapers	2.10	1.15
3) Websites	2.45	0.97
4) Blog Posts	1.57	0.91
5) Forums	1.76	0.99

Note. Observed range in all variables 1–5.

Statistical Analyses

The aforementioned descriptive and reliability analyses were conducted with IBM SPSS Statistics 26, and analyses related to latent profiling were conducted using Mplus version 8 (Muthén and Muthén, 1998–2017). Before we explain latent profiling in more detail, it needs to be specified that we used saved factor scores of online research and comprehension from our previous study (Kiili et al., 2018). In this previous study, we used confirmatory factor analysis (CFA) to validate the ORC assessment and the theory-based structure of the ORC model with the same sample of 426 sixth graders. We used the weighted least square mean and variance adjusted (WLSMV) estimator, since the ORC variables were ordered categorically (Li, 2016). To ensure acceptable model fit, we used the following cutoff criteria: χ2-test (ns, $p > .05$), root mean square error of approximation (RMSEA) < 0.06, and Tucker–Lewis index (TLI) and comparative fit index (CFI) ≥ 0.95 (Hu and Bentler, 1999). The comparison of nested ORC measurement models was implemented in Mplus with a DIFFTEST option. We summarize the results of this comparison in Appendix A.

The validation of the ORC model confirmed the following basic structure: (1) locate, (2) evaluate, (3) synthesize, and (4) communicate information. Further, this model suggested that evaluation of information be divided into two factors: (2a) confirming the credibility of information in more credible texts and (2b) questioning the credibility of information in less credible texts. Synthesizing was also divided into two factors: (3a) identifying main ideas from a single online text and (3b) synthesizing information across multiple online texts. Altogether, the final six-factor model fit the data very well [$\chi^2(75) = 83.57$, $p = .233$; RMSEA = .02; CFI = 1.00; TLI = 1.00], and the correlations between these six component skills varied from .29 to .73 (Kiili et al., 2018). McDonald's omega reliability coefficient (1) for locating was .48, (2a) for confirming the credibility of information in more credible texts was .58, (2b) for questioning the credibility of information in less credible texts was .79, (3a) for identifying main ideas from a single online text was .57, (3b) for synthesizing information across multiple online texts was .93, (4) and for communicating was .81. These factor scores were saved and standardized ($M = 0$, $SD = 1$). For our supplementary sample (23 students) in the current study, we calculated the ORC factor scores similarly, one student at a time, as we did above when calculating the reading fluency factor scores.

Next, the saved ORC factor scores were used to group students according to their ORC performance by applying latent profile analysis (LPA). LPA is a person-centered approach that helps us understand individuals' different patterns of certain criteria variables (see, e.g., Mäkikangas et al., 2018). We applied LPA[1] to identify different online reading performance profiles in relation to the six ORC component skills. In these analyses, we used a robust maximum likelihood (MLR) estimator. Furthermore, in order to evaluate the model and choose the optimal number of profiles, we used Akaike information criteria (AIC), Bayesian information criteria (BIC), sample-size adjusted Bayesian information criteria (aBIC), and the Vuong-Lo-Mendell-Rubin (VLMR) and adjusted Lo-Mendell-Rubin (aLMR) likelihood ratio tests. The smaller the values of the AIC, BIC, and aBIC, the better the model (Nylund et al., 2007). The significant p-values (<.05) of the two likelihood ratio tests indicate the better fit of the estimated model

than the model with one fewer profile (Nylund et al., 2007). Furthermore, we reported entropy values for all models. Entropy values range from zero to one, and the values approaching one indicate a better fit (Asparouhov and Muthén, 2014a).

Alongside the aforementioned criteria, the substantive meaning and theoretical relevance of the model solutions were considered. We also reported the average latent class probabilities for the best-fitting LPA model. As recommended in previous research (see, e.g., Peugh and Fan, 2013), all LPA models were conducted with unequal means and variances across the profiles. Finally, we conducted auxiliary analyses in order to examine students' ORC profiles against the relevant criterion variables, such as students' learner groups and reading habits. As suggested by Asparouhov and Muthén (2014b), we used the DCAT option for categorical variables (learner group variables), and the BCH option for continuous variables (reading habit variables). To also be able to use the MLR estimator in the auxiliary analyses, we used saved BCH weights.

Results

Online Research and Comprehension Performance Profiles

To find the most appropriate model describing ORC performance, nine models were estimated. As shown in Table 3, the VLMR and aLMR tests suggested that a four-profile solution would provide the best fit. However, the information criteria, such as AIC, BIC, and aBIC, suggested that a model with additional profiles would be more suitable. All the aforementioned information criteria had lower values in the consequent solutions. We chose the model with a seven-profile solution because the BIC value started to increase in further solutions, and the entropy value did not get any better (Table 3). Based on previous research, BIC value seems to be the most relevant of the information criteria considered (Nylund et al., 2007). The seven-profile solution was able to describe the performance profiles in a detailed and comprehensible way. Moreover, the classification quality of the seven-profile solution was high: the average latent class probabilities for the most likely latent class membership varied between .87–.98.

Figure 2 shows the seven identified performance profiles: (1) very poor performers (7.6%), (2) poor performers (5.7%), (3) below-average performers (22.5%), (4) average performers with low questioning credibility scores (13.3%), (5) average performers (22.7%), (6) good performers (22.9%), and (7) top performers (5.3%). Most of the profiles were related to the level of performance across all six ORC component skills, with one exception. As Figure 2 shows, the average performers with low questioning credibility scores were quite near the average in other areas but performed below average in questioning the credibility of information in less credible texts.

Online Research and Comprehension Performance Profiles Among Different Learner Groups

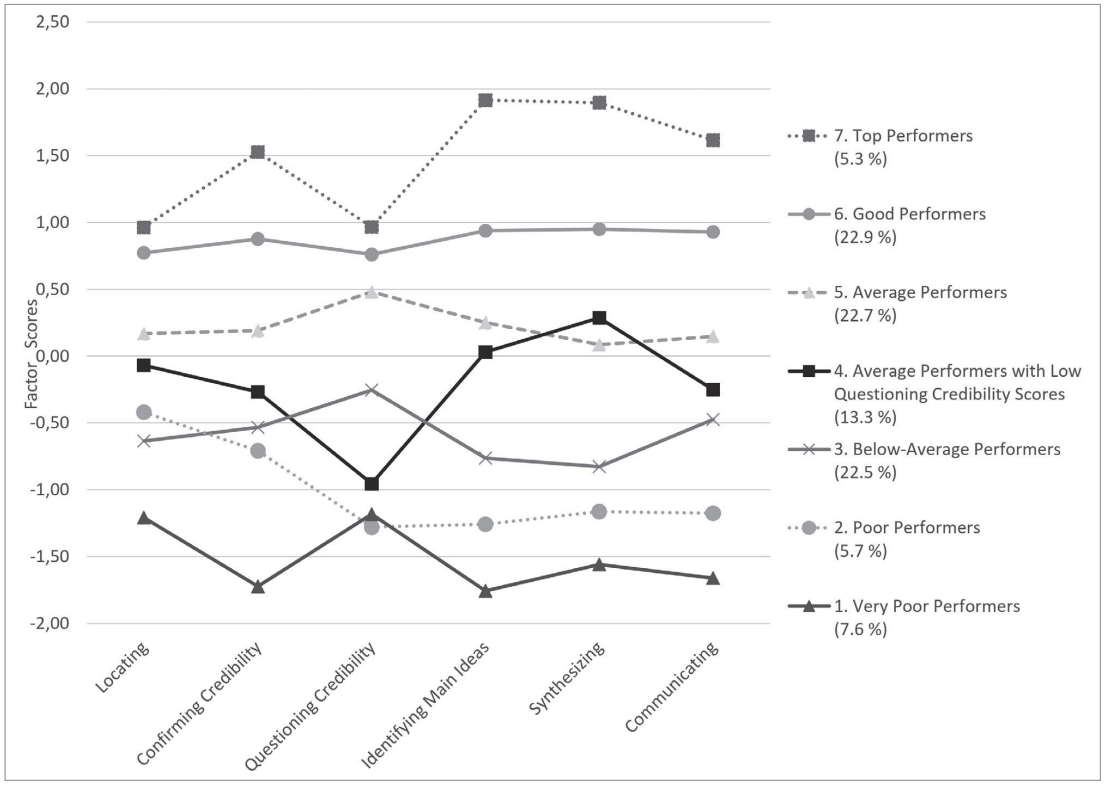
Table 4 shows the distributions of different learner groups and performance profiles with pairwise comparisons. When students had reading difficulties and/or difficulties with attention and EF, the level of their ORC performance decreased. The trend was the opposite among the students without identified difficulties. The proportion of students without these difficulties increased as the level of ORC performance increased. However, a few of students with

TABLE 3
Information Criteria, Statistical Tests, and Entropies of the Different Online Research and Comprehension Performance Profiles

Profiles	AIC	BIC	aBIC	VLMR (*p*)	aLMR (*p*)	Entropy
1	7447.89	7496.82	7458.74	-	-	-
2	6346.83	6448.77	6369.43	.000	.000	.88
3	5963.34	6118.29	5997.70	.002	.002	.87
4	5783.08	5991.04	5829.19	.03	.03	.88
5	5714.22	5975.18	5772.08	.26	.27	.87
6	5647.76	5961.74	5717.38	.02	.02	.89
7	5589.90	5956.89	5671.27	.06	.06	.89
8	5543.30	5963.29	5636.42	.19	.19	.89
9	5502.11	5975.12	5606.99	.25	.25	.89

Note. AIC = Akaike information criterion, BIC = Bayesian information criteria, aBIC = sample-size adjusted Bayesian information criterion, VLMR = Vuong-Lo-Mendell-Rubin likelihood ratio test, aLMR = Lo-Mendell-Rubin adjusted likelihood ratio test.

FIGURE 2
Performance in Each Component Skill by Online Research and Comprehension Performance Profiles



Note. Standardized factor scores for each component skill were used in the analyses.

the difficulties performed better than could be expected, based on their deficiencies.

Of the students with *reading difficulties*, 59.0% belonged to the lowest three performance profiles. Further, pairwise comparisons also showed that students with reading difficulties had a higher probability of being poor performers and below-average performers than a good or top performer. Of the students with teacher-rated *attention and EF difficulties*, 67.5% belonged to the lowest three performance profiles. Pairwise comparisons also showed that students with attention and EF difficulties had a higher probability of belonging to the group of very poor performers and below-average performers than belonging to the highest performance profiles. Notably, the proportion of students with attention and EF difficulties (30.3%) in the lowest performance profile was higher than the proportion of students with reading difficulties (12.1%). From students with *comorbid difficulties* in reading as well as attention and EF, 82.4% belonged to the lowest three performance profiles. Pairwise comparisons showed that students with comorbid difficulties had a higher probability of being very poor performers and below-average performers than either good or top performers.

Of note is that some students with the aforementioned difficulties performed at average and good levels of ORC: 27.5% of students with reading difficulties and 16.2% of students with attention and EF difficulties belonged either to the group of average performers or to the group of good performers. Only one student with comorbid difficulties reached the level of average performers. From students without these identified difficulties, only 4.4% belonged to the group of very poor performers, and only 3.8% to the group of poor performers. Further, all top performers were students without identified difficulties.

Online Research and Comprehension Performance Profiles and Reading Habits

As shown in Table 5, reading books had the strongest association with students' ORC performance. When compared to all other performance profiles, very poor performers ($M = 1.78$) read books very seldom, less than 1–2 times per

TABLE 4
Distributions of Learner Groups in Different Online Research and Comprehension Performance Profiles and the Significance of the Differences of Distributions Between the Profiles

Criterion Variable		1. Very Poor Performers	2. Poor Performers	3. Below-Average Performers	4. Average Performers with Low Questioning Credibility Scores	5. Average Performers	6. Good Performers	7. Top Performers	Total f / % Within LD Group	Overall Test for Equality of Distributions	Pairwise Comparisons
Students with Reading Difficulties	*f*	4	6	13	6	6	4	0	39	$\chi 2(6) = 43.72$, $p < .001$	2, 3 > 6, 7 4, 5 > 7
	% within a learner group	10.30	15.40	33.30	15.40	15.40	10.30	0.00	100		
	% within a profile	12.10	24.00	13.30	10.30	6.10	4.00	0.00			
	SE	0.07	0.10	0.04	0.05	0.03	0.02	0.00			
Students with Attention and Executive Function Difficulties	*f*	10	4	11	6	4	2	0	37	$\chi 2(6) = 43.04$, $p < .001$	1 > 3, 5, 6, 7 3 > 6, 7
	% within a learner group	27.00	10.80	29.70	16.20	10.80	5.40	0.00	100		
	% within a profile	30.30	16.00	11.20	10.30	4.00	2.00	0.00			
	SE	0.09	0.09	0.04	0.07	0.02	0.01	0.00			
Students with Comorbid Difficulties in Reading and Attention and Executive Function	*f*	4	2	8	2	1	0	0	17	$\chi 2(6) = 18.55$, $p = .005$	1, 3 > 4, 6, 7
	% within a learner group	23.50	11.80	47.10	11.80	5.90	0.00	0.00	100		
	% within a profile	12.10	8.00	8.20	3.40	1.00	0.00	0.00			
	SE	0.07	0.06	0.03	0.00	0.01	0.00	0.00			
Students Without Identified Difficulties	*f*	15	13	66	44	88	94	23	343		
	% within a learner group	4.40	3.80	19.20	12.80	25.70	27.40	6.70	100		
	% within a profile	45.50	52.00	67.30	75.90	88.90	94.00	100.00			
Total	*f*	33	25	98	58	99	100	23	436		
	% within a profile	100	100	100	100	100	100	100			

Note. Frequencies and proportions of learners belonging to a certain performance profile is based on probabilities.

TABLE 5
Students' Reading Habits in Different Online Research and Comprehension Performance Profiles and the Significance of the Differences of Distributions Between the Profiles

Criterion Variable	1. Very Poor Performers		2. Poor Performers		3. Below-Average Performers		4. Average Performers with Low Questioning Credibility Scores		5. Average Performers		6. Good Performers		7. Top Performers		Overall Test for Equality of Distributions	Pairwise Comparisons
	M	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*		
Print Reading Habits																
Books	1.78	0.17	2.38	0.20	2.60	0.13	2.83	0.17	2.88	0.13	3.33	0.13	3.47	0.32	$\chi^2(6) = 67.67$, $p < .001$	1 < 2, 3, 4, 5, 6, 7 2 < 5, 6, 7 3 < 6, 7 4, 5 < 6
Newspapers	1.94	0.20	1.52	0.16	1.80	0.09	1.89	0.14	2.20	0.13	2.02	0.12	1.71	0.19	$\chi^2(6) = 15.19$, $p < .05$	2 < 5, 6 3, 7 < 5
Magazines	1.81	0.18	1.34	0.10	1.57	0.09	2.02	0.17	1.95	0.11	1.93	0.09	1.67	0.13	$\chi^2(6) = 31.53$, $p < .001$	2 < 1, 4, 5, 6, 7 3 < 4, 5, 6
Comics	2.41	0.17	2.67	0.23	2.99	0.15	2.75	0.19	2.75	0.15	2.82	0.15	2.54	0.28	$\chi^2(6) = 7.29$, $p = .30$	-
Digital Reading Habits																
Ebooks	1.00	0.00	1.00	0.00	1.10	0.05	1.07	0.05	1.08	0.04	1.11	0.05	1.13	0.14	$\chi^2(6) = 20.25$, $p < .01$	1, 2 < 3, 5, 6
Online Newspapers	1.93	0.22	1.78	0.20	2.10	0.12	2.07	0.19	2.07	0.14	2.10	0.12	2.13	0.28	$\chi^2(6) = 2.57$, $p = .86$	-
Websites	2.16	0.19	2.20	0.17	2.27	0.11	2.41	0.15	2.47	0.10	2.60	0.11	2.69	0.20	$\chi^2(6) = 10.99$, $p = .09$	-
Blog Posts	1.30	0.15	1.18	0.09	1.49	0.09	1.55	0.13	1.50	0.10	1.83	0.12	1.73	0.17	$\chi^2(6) = 25.45$, $p < .001$	1, 3, 5 < 6 2 < 3, 4, 5, 6, 7
Forums	1.84	0.22	1.50	0.12	1.71	0.11	1.62	0.15	1.78	0.11	1.82	0.11	1.88	0.24	$\chi^2(6) = 5.56$, $p = .47$	-

Note. Observed range in all variables 1–5.

month. Further, poor performers (M = 2.38) and below-average performers (M = 2.60) read books less frequently than good (M = 3.33) and top performers (M = 3.47). There were also differences in reading books for those performing at the average levels of ORC. For instance, average performers with low questioning credibility scores (M = 2.83) and average performers (M = 2.88) both read books less frequently than good performers.

Our results also show that poor performers (M = 1.52) read newspapers less frequently than, for example, average performers (M = 2.20) and good performers (M = 2.02). Interestingly, poor performers did not differ from top performers (M = 1.71), but this may be because both profiles consist of less than 6% of the students in the whole sample. Further, poor performers (M = 1.34) and below-average performers (M = 1.57) read magazines less frequently than, for example, average performers (M = 1.95) and good performers (M = 1.93). Another interesting finding is that the group of very poor performers did not differ from the highest-performing profiles in reading newspapers and magazines. Finally, the profiles did not differ in the reading frequency of comics.

When we compared students' ORC profiles in relation to their digital reading habits, we noticed that very poor performers (M = 1.30), poor performers (M = 1.18), below-average performers (M = 1.49), and average performers (M = 1.50) all read blog posts somewhat less frequently than good performers (M = 1.83). Further, sixth-grade students also differed from each other in the reading frequency of ebooks, but the differences were very small, as students of this age read ebooks very seldom. We did not find any differences between students representing different ORC profiles with regard to reading online newspapers, websites, and forums. Overall, the mean values showed that students seemed to read print texts more often than digital texts. However, our results suggest that the medium does not matter as much as the length of the texts. It seems that reading longer texts (books and blog posts), in particular, is associated with students' online research and comprehension performance.

Discussion

This study sheds light on inter-individual differences in students' online research and comprehension performance. First, we were interested in exploring students' ORC performance profiles by using a person-centered approach, specifically latent profile analysis. Second, as most previous research has concentrated on regular learners, this study provides new knowledge about how students with reading difficulties, difficulties in attention and EF, or comorbid difficulties in both areas are able to face the demands of working with online information. Third, as an additional layer of investigation, we also provide information on how students' reading habits are associated with their ORC performance.

Online Research and Comprehension Performance Profiles

When examining students' ORC performance with latent profile analysis, we captured seven profiles. The profiles, with one exception, reflected students' performance levels across all six ORC component skills, ranging from very poor performance to top performance. This is to say that students who belonged to very poor performers or poor performers struggled more or less with all component skills, whereas good and top performers were quite skilled or skilled in all areas.

For example, top performers were very likely able to effectively locate relevant resources and adequately evaluate the credibility of resources regardless of their quality. Top performers were particularly skilled in identifying relevant ideas from single resources, synthesizing ideas across resources, and communicating a justified, source-based stance in their emails. In contrast, it was highly likely that very poor performers did not perform well in any of these areas. For instance, very poor performers were slow in locating relevant online resources and inadequate in evaluating the credibility of these resources. They identified only a limited number of the main ideas presented in the resources and remained short and shallow when communicating their stance in the email. The ORC performance of students who belonged to the profiles of below-average and average performers fell between these extremes.

The profiles reflecting performance levels across different component skills are in line with our previous research showing that although all six ORC components independently contribute to students' online reading performance, they also form a common construct of students' ORC performance (Kanniainen et al., 2019). Interestingly, there was one profile that did not merely reflect the performance level across all the component skills. This profile was labeled average performers with low questioning credibility scores. Students belonging to this profile were quite near the average in other areas but performed clearly below the average in questioning the credibility of information in less credible texts. This result suggests that questioning the credibility of an online resource that is biased or lacks expertise is particularly challenging for some students (Kiili et al., 2018; Pérez et al., 2018).

Finally, we applied (see footnote 1) the multilevel latent profile analysis to examine whether the proportional distributions of the single-level ORC profiles varied across classrooms. However, we did not find any statistically significant differences as a function of students' classrooms. Nevertheless, these kinds of multilevel differences may be possible with a larger sample; this remains for future work to explore.

How Do Students with Reading Difficulties and/or Difficulties in Attention and Executive Function Perform Online?

Our results indicate that students with reading difficulties also face difficulties when reading to learn from online information. This finding is aligned with previous research showing that slow and inaccurate decoding and reading fluency are often associated with difficulties in reading comprehension (e.g., Hulme et al., 2015; Lyon et al., 2003) and that poor comprehension skills are associated with low ORC performance (Coiro, 2011; Kanniainen et al., 2019). Web-based reading environments may also place an extra demand on students with reading difficulties if text and knowledge construction require written responses, as was the case in the ORC task we used. Namely, recent review studies (Galuschka et al., 2020; Reis et al., 2020) have shown that writing difficulties are very common among learners with reading difficulties.

In addition, students with teacher-rated attention and EF difficulties faced challenges online, as has also been shown in previous studies (Caccia et al., 2019; Kanniainen et al., 2021). Interestingly, the proportion of students with difficulties in attention and EF in the profile of very poor performers was much higher than the proportion of students with reading difficulties. Attention and EF difficulties rated by teachers included, for instance, difficulties focusing attention on instructions and difficulties completing tasks. This finding suggests the severe nature of difficulties in attention and EF when reading to learn from online information. Specifically, during the ORC task, students were required to focus and shift their attention between different online reading processes, such as critical evaluation of information, and synthesizing information across multiple online texts. They were also required to focus and shift between different kinds of information locating and writing tools, such as a search engine, a social networking site, and a notetaking tool. It might be that there was not enough working memory capacity left for planning and writing their answers, even though students were able to use the notetaking tool. Successful meaning construction in written responses requires planning, as planning enables writers to construct meanings by organizing their ideas into a meaningful structure (e.g., Flower and Hayes, 1981; McNamara et al., 2019).

Comorbid difficulties in reading and attention and EF caused the most severe difficulties in students' ORC performance, suggesting the need for instruction that could support these students' ORC performance. Additionally, there were also students without these identified difficulties who nonetheless had significant difficulties in the ORC task. This indicates the importance of additional work designed to understand what causes these students' poor performance. For instance, do motivational aspects play a role beyond cognitive processes (see, e.g., Afflerbach, 2016)? Aspects such as boredom and frustration have been speculated to cause poor performance in multiple text reading if students, for example, end up interrupting their task execution too early (List and Alexander, 2019).

Surprisingly, a couple of students with reading difficulties or difficulties in attention and EF performed better than would be expected based on their deficiencies. This finding suggests that these students may have developed compensatory strategies to overcome the challenges of online reading. For example, Leinonen et al. (2001) found that some adult learners with reading difficulties seem not to be disturbed by their errors when reading. They also found that some of these struggling adult readers reported reading a large number of books per year, which seemed to enhance their lexicon and thus compensate for their inaccurate reading fluency. Our result that good ORC performers reported reading books more frequently than, for example, very poor and poor performers may indicate that reading books could be one compensatory mechanism for those above-average performing students with reading difficulties or difficulties in attention and EF.

Further, in a small case study by Castek et al. (2011), they noticed that two of the four struggling readers were able to manage multiple windows effectively when, for example, reading a task assignment in one window and using a search engine in another, the browser window. Also, Andresen et al. (2019b) found that in a group of four students with reading difficulties, there was one who was able to compensate for reading deficiencies by dedicating time to the task. However, more research is needed to understand students' possible compensatory strategies and mechanisms for overcoming their reading difficulties or difficulties in attention and EF when working with online information. This understanding would help educators in designing instruction to address the needs of students with difficulties.

Students' Reading Habits in Different Online Reading Profiles

With respect to students' reading habits and their online research and comprehension performance, we found that reading books had the strongest association with students' ORC performance profiles over reading newspapers, magazines, and comics. This finding supports evidence from traditional reading research showing strong relations between students' book-reading frequency and reading comprehension level over reading of other materials (Pfost et al., 2013; Spear-Swerling et al., 2010; Torppa et al., 2020). Reading books has also been found to be a strong predictor of students' vocabulary (Pfost et al., 2013), and vocabulary knowledge again seems to be associated with comprehension (for a review, see Cervetti and Wright, 2020).

In contrast to traditional reading research, in which digital reading habits have shown negative associations with students' reading comprehension (Pfost et al., 2013; Torppa et al., 2020), we found that reading blog posts and ebooks was positively associated with students' ORC performance profiles. Reading online newspapers, websites, and online forums, however, had no associations. These partly contradictory findings might relate to the fact that traditional reading research has seen digital reading habits somewhat narrowly from the perspective of social online engagement. For example, Pfost et al. (2013) and Torppa et al. (2020) included reading materials such as emails, instant messages, and forum posts, but not any materials, such as ebooks and online news (cf. Lupo et al., 2017). Moreover, even though Torppa et al. (2020) also included blog posts, they included all the digital texts under the same composite score. However, their relatively low alphas (varying between .46–53 in grades six to nine) seem not to support the unidimensional nature of reading different forms of digital texts. Thus, our findings that reading blog posts and ebooks is associated with ORC positively seems noteworthy. To make the comparison between previous studies and the present study easier for the reader, we also included a correlation matrix of the students' ORC component skills and reading habits in Appendix B.

Based on the latent profiling, of note is that reading longer and more vocabulary-rich texts, such as books, blog posts, and ebooks, was associated with students' online reading performance, while reading texts that were shorter in length and probably narrower in vocabulary, for example comics and online forum posts, had no statistically significant associations. Blog posts have been seen as less reliable online resources because blogs are often personal publishing (e.g., Perez et al., 2018). Some, however, do see blogs as useful, at least for second language vocabulary learning (Arndt and Woore, 2018). Further, even though the sixth graders did not, for instance, differ in reading online news, and they read ebooks quite rarely, reading these kinds of digital texts may become a stronger predictor among older students, as students' attitudes toward print and digital reading are often changeable and older students seem to prefer digital media (Jang et al., 2021). Saying this, we should be cautious in giving a certain image that reading digital text has only a negative influence on comprehension. In fact, text length and richness seem to matter more than the reading medium. We could leverage this understanding into advanced pedagogies that reading longer and versatile texts both on paper and on digital formats may have a positive influence on learners' ORC performance.

Limitations and Future Research

The present study has five important limitations that suggest avenues for future work. First, the ORC assessment scores may provide an overestimation of students' online reading skills. This is because there were prompts and guidance included in the assessment. For instance, the avatar gave the right link to the correct online resource if a student failed the locating task. However, in real-world online reading situations (e.g., using the Internet and search engines to complete school assignments), students are not typically provided with the correct online resource. Thus, especially students with different learning-related difficulties may get frustrated and quit the task faster if they are unable to locate relevant online resources. Although this remains for future studies to investigate, practitioners should be aware of this overestimation possibility and, for example, pay close attention to how poor locating skills can influence students' ORC performance even more in real-world web-based reading environments. However, our choice for this task design allowed us to investigate performance in the other tasks measuring other component skills of ORC (e.g., evaluation of the credibility of information) without the consequence of failing to find the right webpages, i.e., as an independent separate skill.

Second, some of the saved ORC factor scores, especially locating, had a low omega reliability value. This low level of reliability may, for example, stem from the limited number of items on the locating component, and thus lead to reduced accuracy of classifications. In other words, there could have been, for instance, average ORC performers with particularly low locating scores; this remains for future work to explore. Nevertheless, the average latent class probabilities showed that the seven ORC performance profiles distinguished well with latent class membership varying between .87–.98. In addition, the 95% confidence intervals of each profile groups' mean scores in the six ORC component skills mainly support the seven-profile solution. The 95% confidence error bars are presented in a bar chart in Appendix C.

Third, for practical reasons, we had a limited amount of time to test students in schools, and thus, we were not able to examine to what extent other cognitive skills, such as working memory capacity, play a role in the ORC performance of students with reading difficulties and/or difficulties in attention and EF (cf. Andresen et al., 2019a; Andresen et al., 2019b). In addition, we did not include any process data, such as verbal protocols and response times, to access the students' online strategies. It remains for future studies to examine the strategies that students with reading difficulties and/or attention and EF difficulties use when reading online, including potential compensatory strategies. Such work could help to inform issues such as reading contexts in which online- and offline-reading skills might best be developed. Future work may also benefit from using performance-based measures of reading habits in addition to the informant-based questionnaires. Following the procedure of the Magazine Recognition Test designed by Stanovich and West (1989), it

would be interesting to develop a recognition test for blogs, for example.

Fourth, we did not have diagnoses, such as dyslexia and ADHD diagnoses, available for all the participating students. For some students, parents reported that reading difficulties and/or difficulties in attention had been identified, but as a formal diagnosis is not a prerequisite for special educational support in Finland, not all students with such difficulties have one. However, we used three different tests for reading fluency that met the criteria displayed for difficulties, such as inaccurate, poor word recognition and decoding skills (Lyon et al., 2003). In addition, the teacher-rating inventory for difficulties in attention and EF has shown good criterion validity (Klenberg et al., 2010a) with the ADHD Rating Scale–IV: School Version (DuPaul et al., 1998).

Finally, the number of students in the comorbidity group was small, which means that the level of diversity may be underestimated in this group. In other words, with a larger group size, also some students with comorbid difficulties could for example appear in the group of good performers. However, in this way our sample better corresponds to the normal population, as it is estimated that 5–15% of school-age children struggle with difficulties related to their learning (American Psychiatric Association, 2018), and in about 15–40% of these cases, learners with reading difficulties, also have, for instance, difficulties in attention and EF (Shaywitz et al., 1995; Willcutt and Pennington, 2000; Willcutt et al., 2005). Thus, the group of 17 students with comorbid difficulties is in line with the previously reported prevalence of these difficulties (hypothetical range in this sample: 3–26 students). It should be noted, at the same time, that our overall sample size is rather big.

Conclusions and Implications

This study broadens our understanding of how students with difficulties in reading and/or difficulties in attention and EF engage in learning from online information. We classified seven latent online research and comprehension performance profiles, from very poor performers to top performers. Not unexpectedly, students with the aforementioned difficulties performed generally lower in ORC than did students without the difficulties. Interestingly, some students—though very few—performed at average and good levels of ORC despite their reading difficulties or difficulties in attention and EF. Students' reading habits, especially reading longer texts, may be supportive for their ORC performance. However, current design does not allow causal conclusions. Active reading may be one of the compensatory mechanisms for well-performing students with reading difficulties or difficulties in attention and EF use, but more research is needed. Further, learning aids and structured learning environments may be beneficial. Consequently, we need courses of action to find more compensatory and supportive elements of online research and comprehension performance for students with reading difficulties and/or difficulties in attention and EF.

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Conflict of Interest Disclosure

Declarations of interest: none.

Ethics Approval Statement

Data and procedures have met the ethical guidelines from our institutions. The Ethical Committee of the University of Jyväskylä gave its approval, and the guardians signed a written consent form for their children's participation.

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There is no such material in the manuscript.

Author Contributions

Laura Kanniainen, Conceptualization; data collection, analysis and interpretation; writing – original draft; writing – review & editing.

Carita Kiili, Conceptualization; data collection, analysis and interpretation; resources; supervision; writing – review & editing.

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Jukka Utriainen, Methodology: data analysis; writing – review & editing.

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Paavo H.T. Leppänen, Conceptualization; funding acquisition; project administration; supervision; writing – review & editing.

Data Availability Statement

The data that have been used are confidential.

NOTE

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[1] As students were nested within 24 different classrooms and eight schools, we calculated intra-class correlations for the six ORC factor included in the LPA. The analysis showed that 0–1.1% of the variance was explained by the differences at the school level and 2.4–7.8% at the classroom level. Thus, multilevel latent profile analysis (MLPA) was used to examine whether the proportional distributions of the single-level profiles varied across the upper-level classes (Mäkikangas et al., 2018). In other words, we used MLPA to examine whether the probability that a student belonged to a specific online research and comprehension profile varied significantly across the classrooms and teachers. However, we did not find a statistically significantly larger probability that a student would belong to a certain profile in some classrooms or with some teachers than in other classrooms or with other teachers (p-values >.05).

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APPENDIX A

Comparison of Nested Online Research and Comprehension Measurement Models

Model Fit Statistics	Four-Factor Model	Five-Factor Model	Six-Factor Model	Chi-Square Difference Tests
$\chi^{2\text{-test}}$ (*df*)	172.20 (84)	143.15 (80)	83.57 (75)	
	$p < .001$	$p < .001$	$p = .233$	
$\chi^{2\text{-diff-test}}$ (*df*)				
Four-Factor Model vs. Five-Factor Model				23.60 (4); $p < .001$
Five-Factor Model vs. Six-Factor Model				43.08 (5); $p < .001$
RMSEA	.05	.04	.02	
CFI	.97	.98	1.00	
TLI	.96	.97	1.00	

Note. The factor loading structures of these three measurement models are presented in our previous work Kiili et al. (2018).

APPENDIX B

Correlation Matrix of Online Research and Comprehension Factor Scores and Reading Habit Variables

	Books	Newspapers	Magazines	Comics	Ebooks	Online Newspapers	Websites	Blog Posts	Forums
Locating Information	.16**	.03	.05	−.01	.09	.10*	.13**	.08	.05
Confirming the Credibility of Information	.30**	.07	.06	.08	.09	.02	.14**	.13**	.06
Questioning the Credibility of Information	.27**	.11*	.07	.11*	.06	.01	.10*	.04	.03
Identifying Main Ideas from a Single Online Text	.33**	.07	.09	.01	.07	.03	.14**	.17**	.05
Synthesizing Information Across Multiple Online Texts	.27**	.05	.12*	−.01	.09	.04	.15**	.23**	.06
Communicating Information	.32**	.04	.15**	.05	.11*	.04	.16**	.21**	.06

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

APPENDIX C

The 95% Confidence Intervals of Each Profile Groups' Mean Scores in the Six Online Research and Comprehension Component Skills