Ocnos (2019), 18 (2): 31-43
DOI 10.18239/ocnos_2019.18.2.1988

OCNOS
Revista de Estudios sobre Lectura

Ocnos
Revista de Estudios sobre lectura
http://ocnos.revista.uclm.es/

Open Access
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Article

Reading comprehension in e-Learning: support strategies and working memory

Comprensión de texto en *e-Learning*: estrategias de soporte y memoria de trabajo

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Received:
07/03/2019

Accepted:
20/06/2019

ISSN: 1885-446 X
ISSNe: 2254-9099

Keywords:
Reading comprehension; Electronic Learning; Reading Strategies; Short Term Memory; Expository Comprehension.

Palabras clave:
Comprensión lectora; Aprendizaje electrónico; Estrategias de lectura; Memoria a corto plazo; Comprensión expositiva.

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Abstract

Support strategies, such as elaboration, rereading, highlighting, memorization, or note-taking, contribute to expository text comprehension. The goal of the present study was to analyze the contribution of different support strategies to expository text comprehension in an e-Learning environment. For this purpose, 224 university students read two expository texts and completed comprehension and reading strategies questionnaires, through an e-Learning platform. Students reported a variety of strategies, which were categorized in three groups: reading and memorizing, note-taking, and digital strategies. For those who read passively, participants with high working memory had significantly better comprehension than those with low working memory; this difference was not significant among those with active strategies.

Resumen

Las estrategias de soporte, como elaborar el material, releer, subrayar, memorizar, o tomar notas, contribuyen a la comprensión de textos expositivos. El objetivo del presente estudio fue analizar la contribución de distintas estrategias de soporte, y su relación con la memoria de trabajo, a la comprensión de textos expositivos digitales en un entorno de *e-Learning*. Para ello, 224 estudiantes universitarios leyeron dos textos expositivos y completaron cuestionarios de comprensión y de estrategias utilizadas durante la lectura, a través de una plataforma de *e-Learning*, de forma remota. Se relevaron distintas estrategias para resolver las tareas, que fueron categorizadas en tres grupos: sólo leer y memorizar, tomar notas y estrategias digitales. Los estudiantes que solo leían pasivamente y tenían baja capacidad de memoria de trabajo comprendían significativamente menos que los que sólo leían y tenían alta capacidad de memoria de trabajo; con estrategias activas no se halló esta diferencia.

Martínez, M., Marrujo, J., Perillo, M., González, F. M., & Burin, D. (2019). Reading comprehension in e-Learning: support strategies and working memory. *Ocnos, 18* (2), 31-43.
doi: https://doi.org/10.18239/ocnos_2019.18.2.1988

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Reading comprehension in e-Learning: support strategies and working memory

Comprehension of expository texts is essential in tertiary and higher education. Studies conducted with teens and university adults have shown that comprehension is affected by the level of specific prior domain knowledge, verbal skills, working memory capacity and metacognitive differences (McNamara, 2007; O'Reilly & Sabatini, 2013; Otero, León & Graesser, 2002). With the advance of information technologies, more and more people read on digital devices. Digital texts are not only defined by their digital medium, but also because they are dynamic, e.g. hypertexts (Amadieu & Salmerón, 2014; Organisation for Economic Cooperation and Development [OECD] 2009, 2011). Readers construct the text as they navigate through different nodes or pages. Therefore, unlike printed texts, digital texts require specific skills because readers need to select and integrate contents through non-linear navigation (Amadieu & Salmerón, 2014; Coiro, Knobel, Lankshear & Leu, 2008; Leu, Kiili & Forzani, 2015; OECD, 2009, 2011). The same skills that are needed for comprehension of printed texts are required to understand digital texts (Amadieu & Salmerón, 2014; Coiro, Knobel, Lankshear & Leu, 2008; Herrada-Valverde & Herrada-Valverde, 2017; Leu, Kiili & Forzani, 2015; OECD, 2009, 2011); however, they interact with digital skills in navigation and search (finding and using links, identifying useful links and knowing where these may lead) and evaluation (discarding non relevant information, identifying authors and sources, determining the credibility and accuracy of sources and contents). For example, low level of verbal skills or poor prior knowledge may result in inefficient navigation (Naumann & Salmerón, 2016), or in selecting links with inappropriate content on a search results page (Salmerón, Cerdán & Naumann, 2015). It has also been noted that teenagers and university students who make very intensive digital use several hours a day have poorer levels of comprehension of digital texts compared to those who make moderate use (Burin, Irrazabal, Injoque-Ricle, Saux & Barreyro, 2018; OECD, 2011).

Digital reading everyday practices, characterised as wide in range, but quick and superficial (Liu, 2012), contrast with expository comprehension metacognitive requirements. Metacognition refers to different aspects of self-regulation, such as planning, monitoring and assessment, and strategic activities (Afflerbach & Cho, 2008; Azevedo, 2005; McNamara, 2007; McNamara & Magliano, 2009; Moos & Azevedo, 2008). In text comprehension, planning includes reading goals and subgoals related to comprehension criteria and previous knowledge activation. Monitoring refers to comprehension errors detection and correction, and strategic regulation. As for strategic activity, Samuelstuen & Bråten (2007) considered text comprehension strategies as procedural knowledge voluntarily used by readers to acquire, organise or transform text information, and to reflect on and lead their own understanding. Mokthari & Reichard (2002) called them support strategies. They include memorising or using mnemonics, searching and selecting new sources of information (a dictionary, for example), re-reading, underlining, marking text, taking notes, making summaries, creating graphs. They are usually classified as superficial (memorization) or deep (organization, elaboration, self-questioning).

Most efficient strategies involve active processing, when readers are engaged with the reading task (McNamara, 2007). In 2009, the Programme for International Student Assessment (PISA) included a questionnaire on strategic knowledge where students were asked to evaluate asked to evaluate "the usefulness of the following strategies for understanding and memorizing the text" (Instituto de Evaluación, 2010, p. 97). The answers with a higher score included activities such as making a summary or explaining difficult words, while those with

a lower score referred to passive reading and re-reading or to passive listening of others' explanations. In the Programme for International Student Assessment (PISA) 2018 (Organisation for Economic Cooperation and Development [OECD], 2019),), strategies were evaluated again, identifying behavioural displays of effort, time and persistence to obtain the desired results as comprehension reading engagement indicators (p. 51). So then, strategies can be classified by activity level, from passive to active. Another way to evaluate them is by categorising the strategies used. Miyatsu, Nguyen & McDaniel (2018), identified five popular study strategies. Re-reading was the most popular one, a passive strategy that consists on reading the contents again, followed by highlighting or underlining the most important items of the text. The other three strategies were active: taking notes, creating graphical aids (hierarchical representations of the study material), and using memory cards.

Higher education through e-Learning platforms continues to grow, both in the case of distance education and in blended-learning courses: The Integrated Postsecondary Education Data System (IPEDS), National Center for Educational Statistics [NCES], quoted by Allen & Seaman (2017) reported that 29.7% of the students took at least one online course. Online learning is a special case of digital text. In order to provide any expository instruction, the thematic material is presented in text or video lessons, in a closed learning content management system, such as Moodle, Blackboard or similar (Clark & Mayer, 2016). In typical courses, information is presented in different lessons, divided into different pages to be read (or into videos, which generally include text information), followed by assessments implemented as multiple-choice or open questions, or a variety of problem solving activities. In digital text comprehension tasks, students have to navigate and integrate the information displayed on different pages. They also need to understand and navigate the learning environment to perform the comprehension and learning tasks properly.

Observational and think aloud protocol studies have described how students navigate and solve digital text comprehension tasks spontaneously, and have shown that students demonstrate different strategic skills (Afflerbach & Cho, 2008; Coiro & Dobler, 2007; Coiro et al., 2008; Leu & Castek, 2006; Leu et al., 2008). In order to construct an integrated mental representation of the digital text content, support strategies can be adaptations of on-paper strategies, such as taking notes, or can be digitally based, such as "righ-clicking" to open different tabs so that they are available for answers, or a "screen capture", or similar. The former are taught and practised at school but the latter are not, and they rely both on more general digital skills and metacognitive aspects such as reading objectives.

Experimental intervention studies have analysed the effects of strategy training, where specific metacognitive or strategic behaviors, such as search strategies, source evaluation, note taking, are modelled and practiced (e.g. Ackerman & Goldsmith, 2011; Ben-Yehudah & Eshet-Alkalai, 2014; Kuiper, Volman & Terwel, 2008; Lan, Lo & Hsu, 2014; Leu et al., 2008; Naumann, Richter, Christman & Groeben, 2008; Salmerón, Llorens & Fajardo, 2015). These studies have shown that adding to the digital reading task a non-automated and unfamiliar strategy imposes attentional and working memory dual-task demands. For example, Ben-Yehuda & Eshet-Alkalai (2014) analysed underlining and highlighting strategies in digital and printed texts among students. In the case of digital texts, digital annotation tools were used too. Those students who took notes in a printed text had better performance in reading and comprehension, both in terms of accuracy and speed, compared to those who worked on a digital text with annotations. ... In a same vein, Naumann et al. (2008) trained university

students in organisation and elaboration strategies, and planning and monitoring metacognitive strategies. Performance was better for high working memory participants, but worse low working memory students. They argued that new strategies might overload working memory until automated, so that that participants with low working memory were more adversely affected.

In synthesis, comprehension strategies, and in particular support strategies, activities to elaborate and integrate text content, have been studied with observational think aloud protocols, and experimental intervention studies. Using support strategies contributes to digital text comprehension, but in a complex way: if a particular strategy is not familiar or automated, it might add to the task load and hinder comprehension performance. Think aloud protocol methodology administration and scoring requirements render them impractical for studies with larger samples. The present study has tried to identify spontaneous support strategies employing a questionnaire methodology.

In addition, most studies reviewed above have explored reading and comprehension in laboratory or classroom controlled environments. In contrast, in the case of computer-mediated distance learning or e-Learning, students perform their tasks at home, without a researcher or teacher's instructions, guidance or monitoring. Also, students use their own computer or mobile device, without any page, site or software access restrictions. The use of digital devices outside of the school or academic environment is linked to leisure, recreational uses, or for social communication purposes, entailing different attentional, processing, and reading practices than studying. Thus, strategic metacognitive aspects might play an important role in e-Learning reading comprehension.

When designing a self-report questionnaire about comprehension support strategies, Samuelstuen & Bratten (2007) showed that the items of a questionnaire that referred to a recently finished reading task were linked to comprehension performance, while an inventory of general strategies referred to generic reading behaviours was not. For this reason, Samuelstuen & Braten (2007) and Bråten & Strømsø (2011) suggested the following aspects that should be taken into account when evaluating comprehension strategies: (1) a specific comprehension task should be administered, to which the questionnaire items should refer; (2) the task should have instructions with information about the reading objective, and inform respondents that they will be asked about how they performed such tasks; (3) in order to minimise the retention interval, the inventory should be administered immediately after completing the task; (4) the wording of the questionnaire items should be tailored to the specific reading task and should not include blanket statements; for example "when I read text X" instead of "when I read". The *Cuestionario de Estrategias de Lectura Digital* (Questionnaire on Digital Reading Strategies) was developed upon this basis (Irrazábal, Saux, Barreyro, Bulla & Burin, 2015). It was created in two phases. In a qualitative first one, spontaneous problem solving strategies in a reading task were analysed. This task was a graded assignment of a psychology course. Students had to read lesson materials, and search for information on the internet, to participate in a forum with questions about a psychology subject (language). They had to elaborate questions about the subject, and respond to other students' questions, in a forum format (one sudents poses a question, the next answers that question and poses a new one, and so on). Upon completing the task, as an ungraded activity, the students were invited to fill in a semi-structured questionnaire asking them how they had performed such task. The activity was conducted by a research assistant who was not their teacher, and the idea that it was an unassessed research activity was reinforced. The strategies were: taking paper and pencil notes; taking notes in a Word, Notepad

or similar document; opening multiple browser tabs; using Google or search engines; using YouTube or other similar websites; asking classmates; and one open question "Other". Upon filling in the questionnaires, questions were made in group interviews (starting with 'Did you use any other resource, did you perform the task differently, besides those of the questionnaire?'). 85 students out of 91 answered (20% were men, age M = 26.85, SD = 7.91), divided into three groups. The strategies most frequently used by the students, and considered more useful, were: taking notes (and preparing the material) in paper, taking notes (and preparing the material) in Word, Notepad or similar, Google or Wikipedia search, keeping several tabs (pages) and the task opened simultaneously in order to check (and copy), and also watching videos on YouTube or similar, and asking other students. The results were reported in a qualitative way, given that students discussed their answers in groups.

The objective of the pilot study was to explore the potential categories of answers to include in a closed questionnaire about online reading strategies. On this basis, in the second study (Irrazábal *et al.*, 2015), 100 first year psychology college students (19 men, 81 women, age M = 20.76, SD = 3.45) participated in a text reading and comprehension questions task in an experimental e-Learning environment. Texts were about high or low prior knowledge subjects, and comprehension questions covered literal and inferential information. After the questions, they reported how they performed the task, using the Questionnaire on Digital Reading Strategies, which included four closed questions and one open question: 1) reading the texts in linear order, and then answering the questions from memory, 2) taking paper-and-pencil notes; 3) copying or taking notes in a notepad or Word document or similar; 4) right clicking on all pages to open multiple tabs to have the information available; 5) Other (describe). Students performed the task remotely, in their usual place of study. The working memory capacity and verbal skills were assessed in another, face-to-face session. In order to analyse the results, strategies were divided in two categories: Active (taking notes in paper, Word or similar, having several pages open, other digital strategies) versus Passive (just reading it all and then answering). Participants with low working memory who adopted a passive strategy had the worst results in comprehension questions (Irrazábal *et al.*, 2015). However, the different strategies were not analysed in detail.

The objective of this study was to analyse the contribution of different spontaneous reading support strategies, and working memory capacity, to understand expository texts in an e-Learning environment. To that end, a sample of first year college students completed the reading and comprehension tasks in an e-Learning platform, at home or at their usual place of study, and then answered a questionnaire on the strategies they employed to perform the tasks. In another face-to-face session, they completed working memory tests, to analyse the relationship between working memory and strategic activity.

Method

Participants

224 university students participated voluntarily in exchange for partial credit in a college course (77% were women, age M = 22.72, SD = 6.39). They signed an informed consent form and received feedback on the research. The study was authorised by an institutional ethics committee.

Materials

Text comprehension. Two expository texts requiring low prior knowledge (Astronomy, Physics) based on previous research, were used (Irrazábal *et al.*, 2015; Burin *et al.*, 2018). The

texts have a similar argumentative structure (general concept, two subordinated concepts, details on each one, general conclusion linking both concepts) and length (1608-1684 words). Texts were divided in eight thematic modules, presented in eight screens, with titles. They could navigate the texts by clicking on a side hierarchical menu, or two hyperlinked words inserted in the text. After reading, the students clicked on "Finish-Go to questions". This button took them back to the course's main page, where they had to follow to the corresponding Questions section, a comprehension questionnaire for each text. Each questionnaire presented ten multiple-choice questions with four options, covering literal information, bridging inferences, or elaborations. Questionnaires were validated in a prior study (Burin *et al.*, 2018).

Texts, questions and the strategies questionnaire were implemented in two courses, one course per experimental condition, counterbalancing the order in which the texts were presented. They were implemented using Moodle v.2.6, on an institutional server (research agency) different from the college site, to emphasize the research nature of the task. Examples of a course and a text are shown in figures 1 and 2, respectively.

Digital reading strategies. An adaptation of the *Questionnaire on Digital Reading Strategies* (Irrazábal *et al.*, 2015) was used for this study. The questionnaire asks about the use of digital reading support strategies employed in a previous reading task: taking notes in paper, taking notes in Word, Notepad or similar, having several open tabs in order to make information available and other (specify). The questionnaire was adapted following the pilot study group discussion sessions, adding possible strategies. Strategies included in this new questionnaire are shown in table 1. For each, participants had to check if they had used such strategy in Text 1, Text 2, both, or none.

Working Memory. In a group face-to-face session, particpants completed the *Letter-Number Sequencing WAIS III* subtest (Wechsler, 2003), adapted for small group administration (Barreyro, Injoque-Ricle, González & Burin, 2015). Digits and letters were sequentially projected onto a screen. The participants observed the sequences of digits and letters and, following a memory cue, had to write the digits in ascending order and the letters in alphabetical order on a protocol sheet.

Procedure

In the first group session, participants signed an informed consent and completed the working memory test. The participants were then randomly assigned to one of the two courses (one started with the text on Physics and the other one with the text on Astronomy); information to join the e-Learning course was provided by e-mail. Participants completed the reading comprehension and strategies questionnaire at home or their usual place of study.

Each course presented the following order: a questionnaire about internet experience, one text to read, questions about the text, another text to read, questions about the text, a metacognitive control questionnaire (not analysed in this study) and the *Questionnaire on Digital Reading Strategies*.

Finally, when all students had finished the tasks, they attended an informative meeting about the study.

Results

Strategies reported by the participants were analysed in first place. They could report more than one strategy. The response rates per strategy are shown in figure 3. Participants who answered "yes" in the first item only were included in the first category ("I read all the text and answered based on what I remembered").

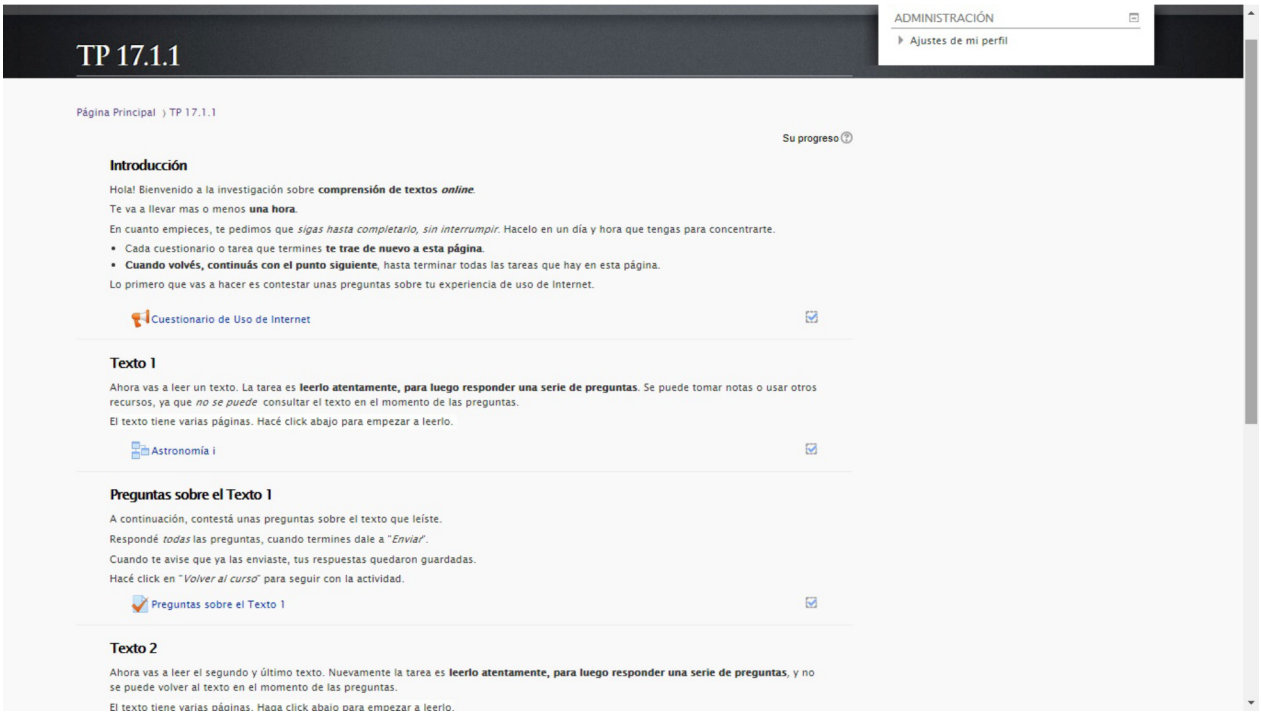

Figure 1. Example of course (cutting).

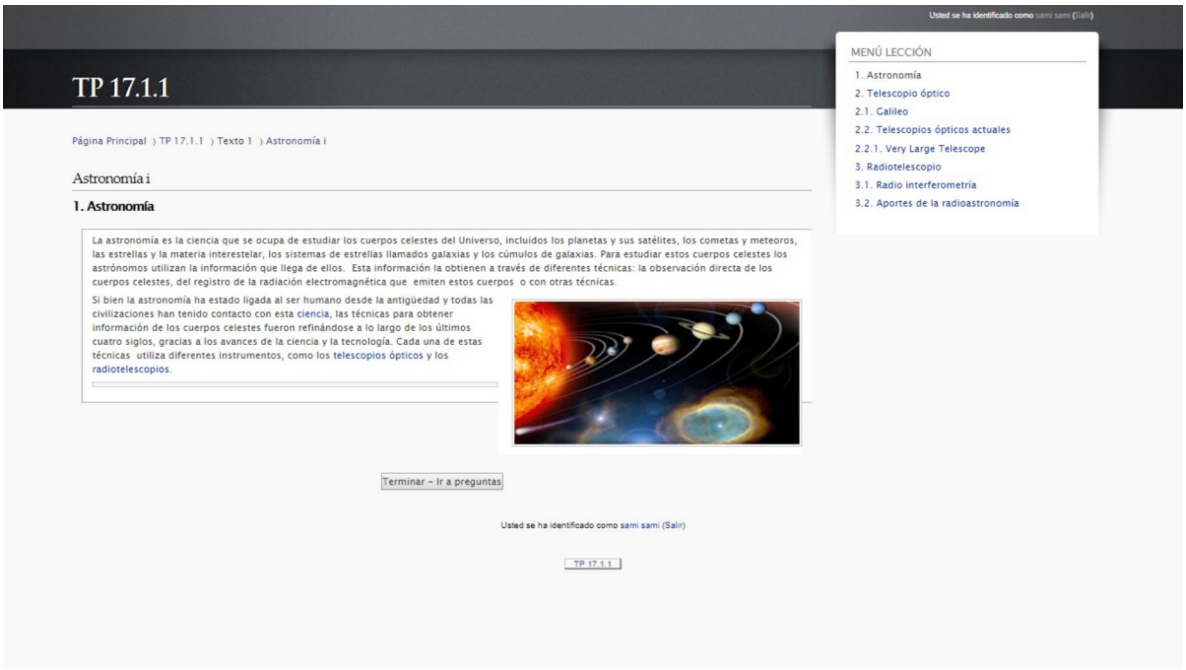

Figure 2. Example of text page (cutting).

Table 1.
Support strategies to understand digital texts

Strategy description	Strategy type
I read all the text and only answered based on what I remembered	Only reads
I took notes in a paper and checked them to answer.	Takes notes
I opened a Word, Notepad or similar document and I took notes, copied and pasted parts of the text to check them.	Takes notes
I right-clicked and opened the text in another tab or checked the text by clicking Back, by checking the History or in a similar way, so I had the materials to answer based on the questions.	Digital strategies
I made screenshots or took a picture of the texts using my mobile, so I was ready to answer.	Digital strategies
I googled it, looked it up on Wikipedia or on a similar website.	Digital strategies
I looked up the questions on Youtube or another video website.	Digital strategies
I asked the questions to other people by chat, Facebook, Whatsapp or similar at the same time.	Digital strategies
Other (specify)	Other digital strategies

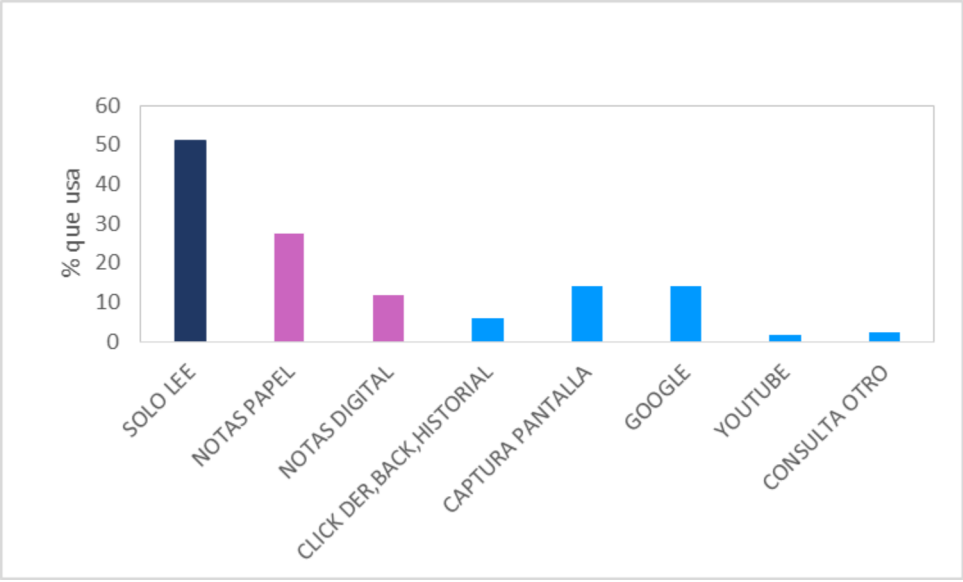

Figure 3. Response rate per strategy used.

50.9% only read and then answer the questions. Among those who adopted one or more active strategies (non-exclusive) 27.6% took notes in paper, 11.7% took notes in Word or similar, 5.9% used browser navigation features (right click, Back, History) to access information, 14% made screenshots or took pictures of the screen using their mobile phone, 14% looked up answers in Google or similar, 1.8% used YouTube or videos and 2.3% asked another person.

Given that some of the categories were reported by a small proportion of participants, and that participants could check more than

one option, in order to analyse the contribution made by each type of strategy, each participant strategic behaviour was re-categorised, according to whether they reported only reading and remembering (50.7%), taking notes in paper or digital (alone or combined with the former) (23.1%), or employing other digital strategies (alone or combined with the former) (26.2%).

To analyse working memory contribution, scores were dichotomised by the median, excluding participants with median values. Therefore, there were two groups: low working memory capacity (N = 105) and high working memory capacity (N = 95).

Total correct responses in both texts was calculated for each participant and expressed as *z*. scores. Total score reliability was Cronbach's α = .624. Descriptive statistics (means, standard deviation) of comprehension scores as a function of strategy and working memory group are shown in table 2.

Table 2.
Descriptive statistics (mean, SD) of comprehension based on the strategy and the working memory (WM)

Strategy	N	M	SD
Low WM	105	-.07	.98
High WM	95	.12	1.01
Only reads + low WM	51	-.18	1.15
Only reads + High WM	51	.27	1.07
Takes notes + low WM	26	-.06	.87
Takes notes + High WM	18	.24	.93
Digital strategies + low WM	28	.11	.69
Digital strategies + High WM	26	-.24	.86

An ANOVA with strategy and working memory (WM) capacity as factors, and comprehension score as dependent variable, followed by paired *post-hoc* contrasts, were performed. Interaction between strategy and WM capacity was significant, F (2, 194) = 3.085, p = .048. Subsequent analyses showed that participants who only read and memorised, and had a low WM capacity, scored less in comprehension than those who only read and had a high WM capacity, t (100) = -2.06, p = .042. In contrast, no significant difference according to WM capacity emerged among those who took notes, t (42) = -1.134, p = .263, or used other digital strategies, t (52) = 1.697, p = .096.

Discussion

This paper analysed the support strategies used by university students when reading digital texts to answer questions in the context of an e-Learning environment. On the basis of previous studies (Irrazábal *et al.*, 2015) and subsequent group discussions with the participants of such studies, different types of strategies were analysed: just reading and remembering when answering the question; taking paper-and-pencil notes; and activities jointly referred to as digital, such as copying or taking notes using a notepad or Word document, opening multiple tabs, navigation employing the browser features, online search with Google or similar, making screenshots using one's computer or mobile phone, asking peers. Interestingly, around 50% of participants did not use any active strategy and only read and memorised; this proportion replicates the one obtained in a previous study (Irrazábal *et al.*, 2015). The range of strategies used by the remaining participants is noteworthy, ranging from taking notes in paper or digital to different strategic behaviour pertaining to the digital format. Taking notes is a very popular and efficient strategy (Miyatsu *et al.*, 2018) that is learnt and practised in formal education. Regarding the varied strategic digital behaviors, this study has identified strategies

that may arise from everyday informal use, such as taking a picture of the computer screen using the mobile phone, looking up answers to questions about a text that has been just read and that may be just one click away, or asking peers. Nevertheless, sample size is one limitation of this study. Future research should analyse how often, and in which contexts, these strategies are used, in larger samples.

The interaction between strategy and working memory showed that for participants who only read and then answered the questions, those with a high working memory capacity had better performance than those with a low working memory capacity. This result is in line with prior research on the link between working memory capacity and comprehension, in both printed and digital texts (e.g. Naumann *et al.*, 2008; Burin *et al.*, 2018). On the contrary, those participants who adopted an active strategy did not show any differences in comprehension as a function of working memory, in line with Irrazábal *et al*. (2015), where it was found that active strategies improved comprehension. It should be noted that we measured spontaneous strategies, as different from intervention studies which showed a cost of implementing strategies for low working memory participants (Naumann et al., 2008). This result also is in line with studies finding an association between reading engagement and reading comprehension (OECD, 2019). Greater reading engagement by using active strategies mitigated the working memory capacity differences in comprehension.

Future research with larger samples could analyse the relative efficiency of the various strategies, used spontaneously and reported through self-reports, in greater depth. Further research could evaluate the effects of training specific strategies (e.g. Salmerón, Llorens & Fajardo, 2015).

In summary, we analysed spontaneous strategies used by university students reading digital texts to answer questions, in the context of e-Learning. A range of active strategies was found, the main one being note taking, in paper or a digital document. It should also be noted that approximately 50% of participants adopted the passive strategy that simply consisted in reading and memorising. For these participants, low working memory capacity led to worse comprehension; active strategies moderated the working memory capacity differences in comprehension. Considering the increasingly important role played by new technologies in educational practices, this study contributes to identify spontaneous strategies in digital reading, especially those arising from everyday digital practices. Identifying strategies and assessing their efficacy would allow for developing training programmes in the context of formal education similar to those aimed at traditional reading.

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