Tablets for all? Testing the screen inferiority effect with upper primary school students

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Educational institutions across the world are increasingly integrating tablets in the classroom, under the assumption that tablets improve students' learning. However, little research has specifically focused on the effects of tablets on reading comprehension of primary school children. Based on previous research with undergraduate students, we tested the hypothesis that primary school students will get more distracted, and subsequently comprehend less, when reading expository texts on tablets, as opposed to paper, particularly when they read under time pressure. In addition, from the lens of the comprehension levels hypothesis, we also analyzed the extent to which higher text comprehension skills could minimize the distractions and comprehension difficulties elicited by tablets during reading comprehension tasks. Results from a study with 182 upper primary school students (range 10-13 years old) indicated that those with low reading comprehension skills comprehended better when reading under time pressure in print than on tablet, but students with high skills were not affected by the reading medium. In addition, we found no evidence that tablets affected on-task attention. We discuss the implications of those results in light of the increasing classroom digitalization programs.

Keywords: text comprehension, medium effect, sustained attention, primary school, tablets.

Tablets are wireless touch-screen devices that can be operated by touching the screen with the fingers. The first studies on the use of hand-held digital devices in education emerged in the mid 2000s (for reviews see Haßler, Major, & Hennessy, 2016; Mulet, Van de Leemput, & Amadieu, 2019). While evidence suggest that tablets can support learning across different domains and tasks (Mulet et al., 2019), little research has specifically focused on the effects of tablets on reading comprehension (Delgado, Vargas, Ackerman, & Salmerón, 2018). In a meta-analysis comparing comprehension across mediums (print vs. digital), Delgado et al. (2018) identified the screen inferiority effect, a significant small-size effect consisting in lower comprehension levels when reading on digital devices than on paper, especially when students read expository texts (see also Clinton, 2019) or under time constraints. Surprisingly, results indicated that new generations show higher screen inferiority than older generations. This suggests that young students nowadays may be particularly inclined to use digital tools in a superficial way, which could result in higher distraction and lower comprehension when reading and studying on tablet. Notwithstanding, Delgado et al. (2018) also identified that the number of studies comparing tablets and printed texts are scarce, and that they have been mostly conducted with undergraduate students. In sum, the impact of tablets on young students' text comprehension remains an open issue. The current study intends to contribute to fill this gap.

First, we review the literature regarding the effects of digital devices on reading comprehension, with a particular focus on the studies that compared tablets and paper. Second, we review previous studies on the effects of tablets on on-task attention. Finally, we introduce one experiment designed to test our hypothesis in a sample of upper primary school students (10-13 years old), and discuss the results in light of the current classroom digitalization programs.

Tablets as reading comprehension devices

Educational institutions across the world are in a race to integrate digital reading devices in the classroom, under the implicit assumption that tablets will help students improve their reading comprehension, as they are more motivating than traditional paper textbooks (e.g., Rikala, Vesisenaho, & Mylläri, 2013). Contrasting to this optimistic view, recent research questions the utility of tablets and other digital devices to support text comprehension (see Salmerón & Delgado, 2019, for a review).

The Shallowing hypothesis attempts to explain the potential detrimental effects of digital devices on reading comprehension, identifying superficial processing as potential mediator (Annisette & Lafreniere, 2017). Most of our current interactions with digital media consist of quick interactions (e.g. skimming messages) driven by immediate rewards (e.g. number of “likes” in response to Facebook post), which has been called the “zapping attitude to text” (van der Weel, 2011). As a consequence, we tend to adopt the habit of processing information on screens in a superficial way. These habits are conceived as “deeply sedimented relational strategies” (Aagaard, 2015), and tend to frame the way we interact with digital devices. Comprehending complex digital information becomes a challenge because students need to overcome this tendency to superficiality in order to construct a rich and coherent representation of the message conveyed in the text. Comprehending a text is the result of a complex set of automatic and strategic processes, which include identifying the meaning of the words, linking the words into idea units, relating ideas from the text and from the readers’ background knowledge, and synthesizing the main message conveyed (Kintsch, 1998). As they advance through the text, readers must connect new information with their ongoing mental model of the text, with the ultimate goal of achieving a coherent representation. But as comprehension is built sequentially as the text unfolds, any distraction during this process may disrupt readers' attempts to link new information with the existing representation. As a consequence, readers may build an incomplete and less coherent representation, especially if the learning situation limits their capacity to revise their comprehension gaps, as when they must read within a fixed time frame.

Our current understanding of the effects of tablets on reading comprehension is still limited. To date, most of the studies comparing in-print versus on-screen reading have been conducted with desktop or laptop computers. In the meta-analysis by Delgado and colleagues (2018), which included studies from 2001 to middle 2017, only 18 out of a total sample of 54 studies used hand-held devices to read on screen (mostly tablets and e-readers). However, the interest in this type of devices as reading tools has increased during recent years as they become more popular[1]. Sixteen of these 18 studies were carried out since 2012, so that if we constraint the time-span to 2012-2017, studies with hand-held devices represent approximately half of the research works. To our knowledge, only six studies have been conducted in school-aged samples, specifically, middle and high school students. Their results varied from no differences in reading comprehension outcomes across mediums (Nishizaki, 2015, Experiment 1; Sackstein, Spark, & Jenkins, 2015; Wells, 2012), to better comprehension for reading in print (Simian et al., 2016), or for reading on a hand-held digital device (McCrea-Andrews, 2014). Additionally, a study by Liang and Huang (2014) did not found differences across mediums when their participants read two texts for either 15 and 30 minutes, respectively, but better comprehension for reading on tablets when they had to read a longer text for 45 minutes.

Most of the existing works present some methodological limitations that compromise their results. Firstly, only the studies by Liam & Huang (2013) and

[1] Note that Amazon's Kindle (the most popular e-reader) was first released in middle 2007 and Apple's iPad (the first tablet) in late 2010.

Sackstein et al. (2015) have been reported in peer-reviewed scientific journals. Second, some of these studies had a sample size particularly small to detect a small effect size (i.e., Liam & Huang, 2013, *N* = 24, within participant design; McCrea-Andrews, 2014, *N* = 36, between-participant design; Nishizaki, 2015, Experiment 1, *N* = 40, between-participant design). Third, none of the six studies controlled for relevant individual differences, such as students' attentional capacity or their reading comprehension skills.

In the current study, we address these limitations of previous research by analyzing a relatively large sample of primary education students, while reading on paper or on tablet, with or without time pressure, and controlling for the students' attentional capacity and reading comprehension skill. According to the Shallowing hypothesis (Annisette & Lafreniere, 2017), reading comprehension should be affected regardless of the digital media used, as people tend to use tablets for the same sort of superficial processing as in other digital devices.

Concerns about tablets at schools are not limited to their effects on reading comprehension. Recent studies suggest that digital devices may also distract students from their learning activities, which could in turn further affect their reading comprehension, as we review in the next section.

Tablets and distraction during reading

Using digital devices for learning purposes, such as when studying course material in a tablet, comes with a potential risk of distraction, as learners must resist the temptation to switch to other appealing but off-task activity, such as playing games or log into social media. Ample evidence indicates that off-task activity while using educational technologies occur frequently within the classroom and when doing homework and studying (see May & Elder, 2018; Schmidt & Vandewater, 2008; van

Der Schuur, Baumgartner, Sumter, & Valkenburg, 2015, for reviews). Most importantly, performance and learning tend to be impaired as a consequence of off-task and multitasking activity.

While most existing studies conceptualize distraction when using digital devices as a consequence of off-task activity, less attention has been paid to the possibility that such devices, even when they are solely used for on-task learning purposes, can be nevertheless distracting. Why in such cases tablets may still induce high levels of distraction? Nowadays, most children have their first experience with tablets at home (Chaudron, Di Gioia, & Gemo, 2018). Children who have grown up using tablets for entertainment purposes at home see this device as a playable tool, which makes reasonable to conclude that they would tend to adopt a more relaxed and superficial processing approach (cf. Annisette & Lafreniere, 2017). This vision of the tablet as a gaming tool would conflict with the perceptions at schools (Downes, 2002), as teachers expect students to invest the necessary level attention to the reading activities performed on a tablet as if they were learning with a non-playable tool, such as a textbook. Interview studies indicate that students and teachers are aware of this conflict, as they perceive tablets in the classrooms as a distracting tool. For example, Chou and Block (2019) reported that after introducing iPads in a high school, teachers described the situation as a “constant battle to direct kids in focusing on tasks at hand”. Further evidence for a potential detrimental effect of tablets on attention comes from studies linking digital media use and mild attention problems (Jensen, George, Russell, & Odgers, 2019). Jensen and colleagues (2019) used a diary method study to explore the relation between frequency of reading on tablets and attention difficulties in a sample of 388 adolescents (10-17 years old), followed daily for 14 days. Analyses at the person-level indicated that students who spend more time using digital devices for school work reported more inattention symptoms on average. Specifically, a 1-hr increase in average daily use of digital tools for school work was linked to a 20% increase in the average reported inattention symptoms.

Direct evidence for the effect of digital reading on on-task attention difficulties comes from the recent study by Delgado & Salmerón (2021). A group of undergraduates read a long expository text, either with or without time pressure. Half of the participants read the text in the actual printed magazine, while half read it in the original PDF on a desktop computer. At intervals during reading, participants were requested to specify if at that time they were focusing their attention on the reading task or not. Results revealed that under time pressure, readers of the printed text reduced their mindwandering as compared to those who read without time pressure. Readers of the digital text, on the contrary, didn't reduce their mindwandering when reading under pressure, and consequently, comprehended less the text than those reading in print (see also Ackerman & Lauterman, 2012). In sum, under time pressure, only participants who read on paper, but not on computer, were able to increase their attention towards a more demanding task.

The question arises as to what extent primary school readers may face similar difficulties to focus their attention in more demanding digital reading tasks (i.e. under time pressure), as found with undergraduate students.

The current study

The current study was designed to test the hypothesis that upper primary school students will get more distracted, and subsequently comprehend less, when reading expository texts on tablets, as opposed to paper, particularly when they read under time pressure. When conducting research with young readers it is essential to consider their comprehension skills, as in comprehensive educational systems such as in Spain, where this study took place, primary school students within the same class show a great variation in terms of reading comprehension skills levels.

Recently, Støle, Mangen, & Schwippert (2020) have attempted to link reading comprehension skills and the screen inferiority effect on a large sample of primary school students. They proposed the hypothesis that the screen inferiority effect would be less pronounced among students with high comprehension skills compared to those with lower skills. During primary school, students continue developing their reading comprehension skills. As students with higher skills tend to have a set of more efficient reading comprehension strategies and have accumulated richer world knowledge (Oakhill & Cain, 2012), they may be better equipped to cope with the challenges imposed by digital reading media. In their study, Støle and colleagues (2020) assessed 1139 ten-year-old Norwegian students, who completed two equivalent versions of a national reading test, one in paper and one on a computer. The authors used the combined scores on those tests to group them by proficiency, with low, medium, and high performers. Overall, results replicated the screen inferiority effect. Analysis by proficiency group revealed that the effect was substantial in all three groups.

Such pattern of effects may discredit the hypothesis that comprehension skills levels moderate the screen inferiority effect. However, those results must be taken with caution for at least two reasons. First, the same variable was used to split the group into three levels of reading comprehension skills (quartiles) and also to compare the medium-effect on reading comprehension (Cohen's *d*). Therefore, a more methodologically sound approach to guarantee the independence between these variables would be using separate tests first to estimate reading comprehension skills and later to compare the medium effect. Second, in Støle et al. (2020)'s study, no specific statistical test was reported to compare potential significant differences between the levels of reading skill on the medium-effect (digital vs. paper). We consider those issues in our study.

From the lens of the comprehension levels hypothesis, we can also argue that higher related-comprehension skills could minimize the distractions elicited by tablets during reading tasks. Readers with higher comprehension levels at the end of primary school are characterized by having better monitoring, inference and integration, comprehension monitoring, and knowledge and use of story structure (Oakhill & Cain, 2012). We hypothesized that these valuable skills could prevent them from adopting a more relaxed and superficial processing approach when reading on tablets, and effectively guide them to decide how much time and cognitive resources they need to invest in processing a text.

Method

Participants and design

A total of 208 fifth and sixth graders from three primary education schools in the region of Valencia, Spain, participated in the experiment. From the original sample, we excluded nineteen students due to missing tasks, four students with learning disabilities, and three students who had recently arrived to the region and were not-proficient on the Valencian language. Accordingly, the final sample included 182 students (10–13 years of age; M = 10.9 years; SD = .79; 42.9% female). Our main interest to analyze this population is the scarcity of studies on the effects of digitalization of reading in primary school (Delgado et al., 2018). There was no IRB or related human subjects governing board, yet APA principles were followed in the study. Data collection in schools was approved by both the regional educational authority (Conselleria d'Educació, Cultura i

Esport, Generalitat Valenciana, Spain), with reference NR/190701, and each corresponding school's governing board. In addition, families were provided with an informed consent form.

We run an a priori power analyses to estimate the number of participants needed, with alpha and beta levels respectively set at .05 and .20 (Faul, Erdfelder, Lang, & Buchner, 2017). A sample of 182 students was appropriate to detect an interaction effect of medium and time pressure on text comprehension scores equal to a partial eta-squared of .07 (minimum necessary sample size = 107), as found by Ackerman & Lauterman (2012).

Materials

Reading comprehension skills test. Reading comprehension skill was assessed using the comprehension subtest of the standardized reading test PROLEC-R, which presents adequate reliability and validity indicators (Cuetos, Rodríguez, Ruano, & Arribas, 2014), in its Valencian/Catalan version. The test was administered as a printed text. This measure included two short narratives and two short expository texts. Each text included four open ended inferential questions, which required to link two pieces of information separated in the text, or to link one piece of information from the text with students' background knowledge. Participants read a passage and then answered comprehension questions concerning that passage. They could not refer back to the passage to answer the questions. Participants were given as much time as they needed to complete the test. Performance was scored as the number of correct answers. Internal reliability of the test in our sample was calculated using the omega coefficient based on a polychoric-transformed correlation matrix. This coefficient was most appropriate than alpha coefficient because the items were not continuous (Gadermann, Guhn, & Zumbo, 2012). Results indicated good reliability in our sample (ω = .83)

Sustained attention test. Students' sustained attention capacity was measured using the Perception of differences test - Revised / CARAS-R (Thurstone & Yela, 2012). This test assesses the ability to quickly and correctly perceive similarities and differences and partially-ordered stimulant patterns. With the use of 60 graphic items, consisting of basic line drawings of faces, the students' task was to determine which of the three faces that make up each element is different from the other two, during three minutes. For this study, we used the 'net right answer score' (total of right answers minus total of wrong answer), which determines sustained attentional efficiency. This standardized test was validated in a sample of 12.190 Spanish secondary students, yielding a high internal consistency (Cronbach's α = .91) and showing positive correlations with a wide set of standardized tests of IQ and reasoning (Thurstone & Yela, 2012). Moreover, it has been previously used to measure students' sustained attention, showing to be a valid measure to discriminate differences in this cognitive capacity between students with ADHD and typical development (e.g., Crespo-Eguilaz, Narbona, Peralta, & Reparaz, 2006).

Frequency of academic digital reading. Students' experience reading in digital tools for study purposes was measured with two items that asked "How often do you read textbooks / novels in digital format?" Participants responded using a licker scale, ranging from 0 (never) to 5 (every day).

Texts. Participants read two expository science texts selected from released items of a national assessment test used by the Spanish Ministry of Education to assess reading competence at the end of primary school (at the end of 6th grade). One of the texts titled "African elephants" described the main characteristics of the species focusing on its differences with respect to Asian elephants and their illegal killing for the commercial trade in ivory. This text was 410-word long with an average of number of words per sentence of 18 words. The second text, titled "Astronauts catch a dragon", explained how two astronauts captured the Dragon spacecraft, which contained material for new experiments about the immune system the astronauts will run in the space. That text consisted of 452 words, with an average of number of words per sentence of 22 words. Two primary teachers verified that the reading level was appropriate for fifth and sixth graders, regarding the vocabulary, syntactic complexity and semantic content.

Participants in the two print conditions read the two texts printed in black on a separate A4 sheet of paper, using Times New Roman, font size 12, and line space 1.5. On the other hand, for the students in the tablet condition the texts have exactly the same appearance, but they were presented on a Lenovo Tab E10 tablet with a 10.1-inch screen and HD resolution. No scroll was needed to read the digital texts.

Text comprehension measure. To assess students' comprehension of the two texts, we used a text comprehension questionnaire consisting of 17 questions. The content and the structure of the questionnaire were based on a national assessment test used by the Spanish Ministry of Education to assess reading competence at the end of primary school (at the end of 6th grade). We used nine questions released from this test, and constructed an additional set of eight questions in order to assess the participants' learning from the text in greater depth. The 17 questions were designed to assess the two levels of understanding proposed in Kintsch's (1998) theory of comprehension. Specifically, the questionnaire was composed of ten text-based questions and seven situation-model questions. The text-based questions assessed the reader's textbase level of readers' comprehension, so the answers were stated literally in one of the texts. However, to answer the seven situation-model questions, students had to be able to make inferences based on the text or prior knowledge. Thus, readers' performance on this type of questions would be reflective of the situation model level understanding of the texts. Regarding the format, the questionnaire includes seven true or false questions, seven multiple-choice questions with four choices per questions and three open-ended questions. The average number of words of the participants' responses on each of the three open-ended questions was 5.1 (*SD* = 3.6, *Range*: 1-24). The procedure for scoring the open-ended questions was the following: First, a trained research assistant scored the three questions using a rubric that included examples of right and wrong students' responses for each question. Second, one of the authors independently scored a random subset of the questions (20%, 36 answers for each of the three question) using the same rubric, with this resulting in an overall interrater agreement of 96.3 %. Specifically, the agreement was 94.4% for the first open-ended question (Cohen's *Kappa* = .88), 100 % for the second open ended-question (Cohen's *Kappa* = 1), and 94.4 % for the third open-ended question (Cohen's *Kappa* = .88). Disagreements were settled through discussion between the two raters, and the research assistant coded the remaining responses. Finally, a single text comprehension score was calculated by averaging students' correct responses across the two texts.

An example of multiple-choice text-based question from the "African elephants" text is: "*What do African elephants ears look like? a) Round and small; b) Very cold; c) They have the shape of Africa; d) Like those of Asian elephants*. A correct response for this question indicates that the reader has understood the sentences of the first paragraph [*African elephants are the largest animals on Earth. They are slightly larger than their Asian cousins are, and can be recognized by their huge ears, which have a shape similar to that of the African continent. However, the ears of Asian elephants are round and smaller*] and reflects that the reader has developed a coherent text-based representation of it. In contrast, the question "*Why is the ivory tusks trade illegal? Because elephants... a) are running out of tusks; b) become extinct; c) do not produce good quality ivory; d) are dangerous for hunters*", which is an example of a situation model-question, cannot be answered solely with literal information stated in the text and require the reader to make an inference combining text content from the fifth paragraph [*Because ivory is so valuable to some humans, many elephants have been killed to remove their tusks. Today, this trade is illegal, but it has not entirely disappeared, and some populations of African elephants remain at risk*] in combination with some information from students' prior knowledge about the illegal trade. Thus, readers' performance on this type of question would be more reflective of a situation model of comprehension.

We also calculated the reliability coefficient omega based on the polychoric correlation matrix. This coefficient was also most appropriate than alpha coefficient in this case, not only because the items were not continuous, but also because the tau-equivalence assumption was violated and a mixed format test was applied (true or false, multiple-choice and open-ended) (Gadermann, Guhn, & Zumbo, 2012). The omega value was .81. Moreover, the fit indices chi squared test [$X^2(119) = 126.977$, $p = .292$], RMSEA (0.02), CFI (0.95) and TLI (0.95) suggested that unidimensional model fits the items. The statistical analyses were carried out using the psych, lavaan, and GPArotation packages implemented in R 3.5.1 (R Core Team, 2018).

On-task attention difficulties measure. We adapted to Valencian the Task-specific Mindwandering Questionnaire developed by Sanchez & Naylor (2018), which consists of five likert-scale questions or statements referencing participants' on-task attention in the reading task they had previously completed. We included only 3 items and simplified their wording to be understood by primary school students. The three items finally used were: 1) "*While you were reading, did you think about things different than the text?";* 2) "*Did you paid full attention to the text?*"; and 3) "*Did you have to re-read a part of the text because you found that you hadn't been thinking about what you were reading?*". Each item had to be rated from 1 (*Almost never*) to 6 (*Almost always*). Omega coefficient showed that the reliability of this measure was acceptable (ω = .74)

Procedure

Students completed the experiment in two parts. In the first part, they were group administered the measures of reading comprehension and sustained attention capacity in the classroom setting (in groups of around 20 students) during a 50-minute regular lecture, with their regular teacher supervising along with four researchers. All students received a folder with the two measures, each of which was completed after a short oral instruction given by one of the researchers. The participants were allowed as much time as they needed to answer the measure of reading comprehension and three minutes to complete the measure of attention.

In the second part, each student was randomly assigned to one the four experimental conditions the "under-time-pressure-tablet group", the "without-time-pressure-tablet group", "under-time-pressure-print group", and the "without-time-pressure-print-group". During this part, participants read the two texts and completed the text comprehension and mindwandering measures individually in groups of four in a quiet room of the school. All the participants within the same group completed the experimental task under the same conditions. They were given the following oral instruction before reading the texts: "You have to read a text with the purpose of learning as much as possible about its content because after reading the text you will have to answer several questions about it. Be aware that you will not be allowed to go back to the texts while answering the questions". Additionally, students in the without-time-pressure conditions were also orally instructed that they were allowed as much time as they needed to read the texts, while the instruction for the participants in the two under-time-pressure conditions was "This task is special, because you will have limited time to read the text. We will let you know when the time is up, and then you must stop reading. While you are reading, we will notify you when you have reached half of the available time, so you can estimate if you have enough time to finish the text or you have to read it faster. If you finish the text before the time runs out, you must re-read the text until we tell you that the time is finished". The participants pertaining to these under-time-pressure groups were given 120% of the time necessary to read the whole text at an average grade speed (Espada, 2003). Thus, the time periods were allocated considering the length of each text and the average reading speed of sixth and fifth graders, respectively, according to norming data of Spanish (Espada, 2003). Specifically, for the text "African elephants" students were given 3 minutes and 48 seconds – 4 minutes (sixth and fifth grade, respectively), while for the text "Astronauts catch a dragon" the time was 4 minutes and 18 seconds – 4 minutes and 36 seconds (sixth and fifth grade, respectively). Of note is that all participants were able to finish reading both texts on the given time. Participants were given an opportunity to ask questions about the procedure prior to starting the experiment. After reading each text, they were given as much time as needed to make their mindwandering judgments and complete the text comprehension questions.

Results

The data and syntax that support the findings of this study are openly available in OSF at https://osf.io/78urq/

Preliminary analyses

Descriptive analyses proved that all variables measured were normally distributed (see Skewness and Kurtosis in Table 1). Pearson correlation showed significant relationships between the expected relations (Table 2). Specifically, scores on the text comprehension questions correlated positively with reading comprehension skills, $r = .51$, $p < .001$, and sustained attention capacity, $r = .27$, $p < .001$, and negatively with on-task attention difficulties, $r = -.28$, $p < .001$. Finally, frequency of digital reading was not significantly related to any of the other variables. Accordingly, that was not included as covariate in the subsequent analyses.

-Table 1 and 2 around here-

Effects of medium and time pressure on on-task attention

To test the hypothesis that reading comprehension skills moderate the interaction effect of medium and time pressure on on-task attention, we ran a between participants ANCOVA with the main effects of medium (paper or tablet) and time pressure (with or without), their interaction, as well as the interaction between medium, time pressure, and reading comprehension skills. Scores on the sustained attention task was used as covariate, and on-task attention difficulties scores as dependent variable. Analysis indicated non-significant results of medium, $F < 1$, time pressure, $F(1, 173) = 1.60$, $p = .21$, $\eta^2_p = .01$, and their interaction, $F < 1$ (see Table 3). Although average means suggest that students who read on tablets experienced higher on-task attention difficulties ($M = 2.43$, $SD = 1.07$) than those who read in print ($M = 2.21$, $SD = 0.92$), high standard deviations partially explained the lack of a significant effect. Contrary to our hypothesis, the three-way interaction of medium, time pressure, and reading comprehension skills was not significant, $F < 1$. Finally, the effect of sustained attention capacity was also non-significant, $F < 1$.

-Table 3 around here-

Effects of medium and time pressure on text comprehension

Next, we tested the hypothesis that reading comprehension skills moderate the screen inferiority effect on text comprehension, by running a between participants ANCOVA with the main effects of medium (paper or tablet) and time pressure (with or without), its interaction, as well as the interaction between medium, time pressure, and reading comprehension skills. Scores on the sustained attention task was used as covariate, and scores on the text comprehension questions as dependent variable. The effects of medium, $F < 1$, time pressure, $F < 1$, or their interaction, $F(1, 173) = 1.98$, $p = .16$, $\eta^2_p = .01$, were not significant. In line with our hypothesis, the three-way interaction of medium, time pressure, and reading comprehension skills was significant, $F(1, 173) = 11.40$, $p < .001$, $\eta^2_p = .21$. The covariate sustained attention capacity was also significant, $F(1, 173) = 3.78$, $p = .05$, $\eta^2_p = .02$, indicating a positive relation between sustained attention capacity and text comprehension scores.

To interpret this three-way interaction, we first divided participants according to their reading comprehension skills by means of a median split of our sample scores (i.e. 12 points). We created two groups, and those with scores lower than the sample median were identified as students with low comprehension skills ($n = 81$), whereas those scoring equal or higher to the sample median were considered students with high comprehension skills (n = 101). In the original norming study of the test the cut off point from "normal range" to "mild difficulties" for both 5^{th} and 6^{th} grade is 11 (Cuetos et al., 2014). Therefore, in our sample the high skilled group was composed of students scoring within the normal ranges, while most in the low skilled group presented mild difficulties.

For each level group, we computed an omnibus ANCOVA with medium and time pressure as independent variables, and scores on the sustained attention task as covariate. For the group of students with high reading comprehension skills, there was no effect of medium, $F < 1$, and a significant effect of time pressure, $F(1, 101) = 11.37$, $p = .001$, $\eta^2_p = .11$, indicating that those students comprehended the text better without time pressure than with time pressure (see Table 4). The interaction was not significant, $F < 1$. Finally, scores on the sustained attention task had a positive significant effect $F(1, 101) = 5.88$, $p = .02$, $\eta^2_p = .06$.

-Table 4 around here-

For the group of students with low reading comprehension skills, results showed non-significant effect of medium, $F(1, 76) = 1.38$, $p = .24$, $\eta^2_p = .02$, and a significant effect of time pressure, $F(1, 76) = 5.79$, $p = .02$, $\eta^2_p = .07$, indicating that these readers also comprehended better the text without time pressure than with time pressure. Those effects were qualified by a significant interaction between medium and time pressure, $F(1, 76) = 4.58$, $p = .04$, $\eta^2_p = .06$. In this group, the effect of the covariate sustained attention capacity was not significant, $F(1, 76) = 2.56$, $p = .11$, $\eta^2_p = .03$. To interpret the interaction, we ran post-hoc contrasts with Bonferroni corrections. As expected, medium exerted a significant medium size influence on text comprehension scores when students with low reading comprehension skills read under time pressure, $F(1, 76) = 6.02$, $p = .02$, $\eta^2_p = .07$, but not when they read without time pressure, $F < 1$.

Discussion

Our study addressed recent calls to clarify the relationship between reading in print or reading digitally, to understand for whom each medium works and under what conditions (Coiro, 2020). The results reveal that reading on tablets, as opposed to reading in print, is particularly detrimental for upper primary school students (10-13 years old) with low reading comprehension skills when they read expository texts under time pressure. However, students obtain similar levels of text comprehension with tablets or printed texts if they possess high reading comprehension skills. While results support the hypothesis that reading comprehension skills moderate the screen inferiority effect on text comprehension, we found no evidence that such relationship existed for on-task attention difficulties.

Individual differences and the screen inferiority effect

Most prior research on the screen inferiority effect has focused on undergraduate populations and has ignored the potential moderating role of individual differences. Our study aligns with recent efforts to clarify such relationships in younger students (Ben-Yehudah & Brann, 2019; Støle et al., 2020), by showing that media effects are qualified by upper primary school students' reading comprehension skills. The fact that young students with high comprehension skills comprehend texts on tablet to the same degree as in print, even under time pressure, suggests that they are able to conceive and relate with tablets as learning tools, and not just gaming devices (Aagard, 2015). On the contrary, less skilled students may still perceive reading on tablets mostly as a situation closer to playing with tools. Such differences in the way students relate to digital devices have been previously documented with regards to the use of cellphones in schools. Beland & Murphy (2016) analyzed cellphone ban policies in UK with large samples of 11, 14 and 16 year-old students. They found that while such programs had no impact on learning of high-achieving students, they produced an increase of 14.2% of a standard deviation in low-achieving students (for similar results in Sweden see Kessel, Hardardottir, & Tyrefors, 2020). How do high skilled students arrive to establish a learning relation with tablets, contrary to their low skilled mates? Potentially, there are several individual and contextual factors that may explain such process.

At the individual level, one could argue that experience with tablets as learning tools should be enough to warrant reading comprehension levels equivalent to those obtained with printed texts. However, our data discard this option, by showing that frequency of reading on tablets has no effect on students' comprehension. Instead, it may be more helpful to look at students' characteristics that allow them to profit from such experiences. Prior research indicates that high skilled readers are more aware of their comprehension difficulties during learning (Oakhill & Cain, 2012). This ability to monitor their understanding allows to detect problems as they arise, and subsequently to correct them, provided that the student knows appropriate learning strategies. For example, while multitasking during a learning session, a high skilled student would perceive that her understanding of the text is not as good as usual, and to solve this she may decide to stop doing other tasks while learning. In the context of digital reading, high skilled readers would be able to realize that their understanding of a text read in a tablet is not as good as when they read on paper, and that in those situations they must do an extra effort to focus. After some practice, they will be able to establish two dissociable relations with tablets, as either learning or playable tools. To corroborate this assumption, future research should specifically assess students' monitoring skills.

Contextual factors can also play a role in shaping students' relations with tablets. As in most cases children initial interactions with tablets at home are aimed to play, once tablets are introduced as learning tools in schools families can play an important role in reshaping children attitudes towards digital media. Specifically, through digital mediation parents aim to regulate and mold their children use of digital devices. Parents model different aspects of the relationships with media, from restricting access to dangerous websites to monitoring an effective use (Nikken & Opree, 2018). Although, to the best of our knowledge, there is no empirical evidence relating parents' mediation of effective uses and learning, we can expect that more active parents may engage in discussions with their children about the importance of separating gaming and learning attitudes towards digital tools. Future research should test those potential causes.

Results from our study also help to broaden the developmental perspective of the screen inferiority effect. From the lenses of the shallowing hypothesis (Annisette & Lafreniere, 2017), typical adult practices with digital media such as text skimming, scanning or substantial social media use, influence the way we interact and think with digital tools. Provided that those are not typical practices experienced in Primary school, how it is possible that children as young as 10 years old showed the screen inferiority effect? Ultimately, the shallowing hypothesis points to relational habits with digital tools that conflict with what can be defined as a learning state of mind, necessary to focus and to deeply comprehend digital texts. In children, such conflicting habits may come from gaming experiences at home. One way to prevent such conflict is to adapt current literacy practices and assumptions in schools, to make them more closely align to children gaming experiences at home (Downes, 2002). However, such approach has its own limitations, as some learning processes, such as deeply comprehending texts, may require extra focus and patience to that found in gaming experiences.

Our study identified reading comprehension skills as a main mediator of the screen inferiority effect with tablets, but other individual factors relevant to comprehension could also influence the way young students read in digital devices. Of particular interest would be to identify factors that affect differentially the way students comprehend texts in tablets or in paper. Potential candidates are cognitive factors that help students to monitor their understanding and to avoid losing track of the comprehension process, such as working memory or inhibitory processes, as well as emotional factors linked to students' reading experiences, such as self-efficacy beliefs towards digital devices.

Finally, our focus on individual differences and development raises an important concern, as lower comprehension levels with digital tools may have long terms consequences in students' development of advance reading comprehension skills. Specially, the screen inferiority effect in our study was particularly evident in the group of students with low reading comprehension skills. Under time pressure, they comprehended significantly less when reading on tablet than when reading on paper. The fact that young low skilled readers are particularly prone to the screen inferiority effect raises the question of how the acquisition of reading comprehension skills would be affected by their continuous use of tablets. According to the Matthew effect in reading (Stanovich, 1986), existing individual differences at one moment determine the extent to which young readers continue developing their reading comprehension skills. As the acquisition of literacy skills relies on prior skills, students that at a particular point had high skills will be able to further develop their skills to a higher extent than those with lower skills. This means that over school grades, the gap between low and high skilled readers is not stable, but rather increases. Future research should address those concerns using longitudinal designs aimed at identifying long term effects.

On-task attention and tablets

Data from the on-task attention questionnaire indicate that reading on tablets, as compared to reading on paper, don't induce increased levels of distraction in young readers, contrary to what has been previously reported with undergraduate students reading on a computer (Delgado & Salmerón, 2021). There are three major differences between those studies, which may help to explain such differences. First, our study focused on 10-12 year old students, instead of undergraduates. As discussed before, many of the reading practices that contribute to a shallow processing, such as skimming, scanning or substantial social media use, are more typical of adult students (Annisette & Lafreniere, 2017). To the extent that such practices involve changing attention focus constantly, they may be responsible for the higher digital distraction experienced by adult readers.

Second, we used a self-reported and retrospective task to measure distraction, instead of the probe-caught technique that interrupts students while reading to measure their mindwandering (Delgado & Salmerón, 2021). From a psychometric point of view, the task we used was reliable and we found some indicators for its validity, as the significant negative correlation between on-task difficulties and text comprehension scores. However, given the different nature of both techniques, we cannot rule out the differences in the results pattern observed are due to the tasks used.

Finally, in our study participants read on a tablet, instead of in a desktop computer, as in the Delgado & Salmerón (2021) study. As we discuss in depth in the next section, tablets may be better suited to support a more focus reading comprehension than computers.

Tablets or computers as reading devices

Evidence for a screen inferiority effect has come mainly from studies using computers as the digital device. In their metaanalysis, Delgado et al. (2018) reported that, among the few studies that had used tablets or e-readers as digital device, there was a non-significant trend to smaller screen inferiority effect than those observed for computers. Overall, results from our study concur with such trend, as detrimental effects of tablets were only found in a subsample of low-skilled participants, but not on the whole students sample. In addition, students reading on a tablet did not show higher on-task attention difficulties than those reading on paper. From this, we can conclude that tablets are not as detrimental as computers for text comprehension.

Accordingly, our results on the interaction between reading comprehension skills and media comprehension don't concur with the pattern reported by Støle et al. (2020), who found a significant screen inferiority effect for all levels of reading comprehension skills, including high skilled students. A major difference between the two studies is the digital medium compared: while in Støle et al. (2020) students used computers, in our study participants read on tablets. Again, this discrepancy suggests that tablets are not so detrimental for comprehension as computers, at least for high skilled readers.

Why tablets could support better comprehension than computers? Mangen & van Weel (2016) have proposed that a major difference between digital reading devices is the extent to which they are compatible with an embodied view of reading. When readers can hold a reading device, such as paper books or tablets, they can establish a physical relation with the device that is compatible with their ongoing comprehension processes. This is not possible in stationary computers, which therefore create a physical barrier with readers.

Although based on our results we must recommend the use of paper texts for reading comprehension tasks, when digital devices are chosen (e.g. due to the lockdown caused by COVID-19), based on previous studies (Delgado et al., 2018; Støle et al., 2020) and on our own results we conclude that tablets should be recommended over computers. However, as there are still a small number of studies that used tablets as reading devices, those conclusions are tentative and should be further corroborated in future research.

Of note is that our study focused specifically on traditional reading comprehension tasks and, accordingly, we cannot generalize the effects observed to other learning situations. Recent reviews about the effectiveness of tablets and school learning indicate that, while perceptions of students' and teachers tend to be positive (Mulet et al., 2019), limitations in the methodology used in previous studies do not allow drawing strong conclusions about its real effectiveness (Haßler et al., 2016).

Conclusions

Our study aligns to recent calls for a more critical and methodological rigorous analysis of the effectiveness of tablets and other digital devices as learning tools (Haßler et al., 2016; Salmerón & Delgado, 2019). Current worldwide investments programs on tablets for schools must be accompanied by a reflection on the purposes that such devices can fulfill. Our results indicate that, overall, tablets are not detrimental for pupil's on-task attention or text comprehension. However, they can be detrimental particularly for low skilled upper primary school students when they read under time constraints. This is not trivial, because reading tasks in schools are usually performed within a limited time frame. Daily needs in classrooms are often associated to efficiency in time management, so that the balance between time investment and achievement outcomes plays a crucial role. Therefore, caution should be taken when introducing tablets as reading devices to low skilled students in upper primary school classrooms.

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Table 1

Descriptive statistics for measured variables

Variable	M (SD)	Skewness (SE)	Kurtosis (SE)	Minimum	Maximum
Sustained attention capacity	37.25 (9.87)	0.11 (0.18)	-0.61 (0.36)	17.00	59.00
Reading comprehension skills	11.47 (2.74)	-0.66 (0.18)	0.10 (0.36)	2.00	16.00
Frequency of academic digital reading[1]	1.9 (.86)	1.15 (.18)	.89 (.36)	.75	5
Text comprehension scores[2]	0.56 (0.16)	-0.22 (0.18)	-0.29 (0.36)	0.06	0.91
On-task attention difficulties	2.32 (1.00)	0.87 (0.18)	0.82 (0.36)	1.00	6.00

Notes. [1] From 0 – never to 5 –every day, [2] In proportion of correct answers

Table 2

Zero-order correlations between measured variables

Variable	1	2	3	4	5
1. Sustained attention capacity	-				
2. Reading comprehension skills	.28**	-			
3. Frequency of academic digital reading	-.02	-.14	-		

4. On-task attention difficulties	-.06	-.02	-.01	-	
5. Text comprehension scores	.27**	.51**	-.12	-.28**	-

Note. $^{**}p < .001$.

Table 3

Descriptive statistics: Effects of medium and time pressure on on-task attention

Medium	Digital		Print	
Time Pressure	Without (*n* = 45)	With (*n* = 44)	Without (*n* = 48)	With (*n* = 45)
M (SD)	2.31 (0.96)	2.55 (1.17)	2.03 (0.77)	2.40 (1.04)

Table 4

Means and standard deviations (in brackets) of text comprehension scores, by medium, time pressure, and reading comprehension skills level (high or low)

Reading comprehension skill level	Medium	Digital		Print	
High	Time Pressure	Without (*n* = 27)	With (*n* = 20)	Without (*n* = 29)	With (*n* = 25)
		0.66 (0.12)	0.56 (0.11)	0.66 (0.12)	0.57 (0.17)
Low	Time Pressure	Without (*n* = 18)	With (*n* = 24)	Without (*n* = 19)	With (*n* = 20)
		0.56 (0.12)	0.39 (0.15)	0.51 (0.18)	0.53 (0.16)

Note. Scores are expressed in proportion of correct answers.