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Precursors of reading text comprehension from paper and screen in first graders: a longitudinal study

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Abstract

Research on text comprehension in relation to the reading medium (paper or screen) has mainly involved undergraduate or high school students. To advance current knowledge on the effects of reading medium, this longitudinal study focused on beginner readers, specifically, the role of precursors in first graders' comprehension of narrative and expository linear texts from reading on paper and computer screen. Working memory and inference skills as cognitive precursors and basic digital skills were measured at the end of preschool (T1); reading text comprehension and word reading, as a control variable, were measured at the end of the first grade (T2). Sixty-three children participated in total. The first graders read four texts, one narrative and one expository, on both paper and computer screen, in a counterbalanced order. Results showed no main effects of the reading medium or text genre, but the interactive effect of these variables was significant. At T2, the children had higher comprehension scores after reading narrative than descriptive texts from paper. In addition, reading from the screen was preferred at post-test, after all texts were presented. As precursors, working memory and inference skills predicted both printed and digital text comprehension. In contrast, basic digital skills predicted only digital text comprehension after controlling for medium, text genre, and word reading.

Keywords Text comprehension · Digital reading · Reading on paper · Longitudinal study · Precursors · Beginner readers

Children born in the digital age, known as digital natives (Prensky, 2001), are growing up in an environment saturated by digital media, in which they interact with tech-

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nologies (Hisrich & Blanchard, 2009). These technologies expose them to a variety of digital texts compared to more traditional texts on paper. The use of digital texts during storybook reading is constantly increasing from preschool onwards (Furenes et al., 2021; Lauricella et al., 2014). When children enter primary school, they also start using digital devices for learning activities, including learning to read. The present study focuses on text comprehension from paper and computer screen in first graders who can read independently.

When considering text comprehension in relation to reading medium, recent meta-analytic research has shown that, at different educational levels, students comprehend better when reading on paper than on screen, although they may prefer digital reading (Clinton, 2019; Delgado et al., 2018; Kong e al., 2018). In addition, meta-analysis has shown that children's comprehension of printed narrative books read by an adult exceeds their comprehension of digital narrative books read to the child by a voiceover (Furenes et al., 2021). However, meta-analyses on the relationship between reading comprehension and reading medium are based on only a very few studies with primary school students. Therefore, we know little about the youngest readers and the precursors that can sustain reading text comprehension from paper and screen. There is no cohesive theoretical framework that concurrently describes the various precursors involved in reading from different mediums (Dahan Golan et al., 2018). However, it is likely that, in reading comprehension from screens, it is not only the well-known cognitive factors that are involved but also skills related to the use of digital devices.

This longitudinal study, part of a wider research project on traditional and digital reading, had two goals. First, we sought to determine whether, in beginner readers at the end of the first grade, text comprehension differentiates across printed and digital mediums when considering both narrative and expository texts, and whether children prefer reading on paper or screen. Second, we sought to understand whether precursors assessed at the end of preschool—specifically traditional literacy skills (i.e., cognitive abilities: working memory and inference skills) and digital skills (i.e., basic digital skills such as navigation skills)—sustain text comprehension from paper and screen, and account for any differences in text comprehension across mediums, after controlling for word reading skills.

Reading from paper or screen?

Whether reading on paper or screen, text comprehension is a coherent mental representation of the meaning of a text. According to the well-known construction-integration model of text comprehension (Kintsch, 1998), such a mental representation is formed when textual propositions (the textbase representation or a more superficial representation) are integrated with the reader's background knowledge to construct a global and deeper representation of the meaning of the text. Text comprehension, therefore, is the outcome of an active, complex process in which both information explicitly presented in the text and implicit information inferred by the reader must be comprehended.

Today, both printed and digital texts are read increasingly frequently. Therefore, a crucial question arises: are reading from paper and reading from screen equal for text comprehension? In recent decades research has flourished on meaning construction from text in relation to reading medium. Four meta-analyses have been published in the last four years, synthesizing accumulated evidence. Three of these works (Clinton, 2019; Delgado et al., 2018; Kong et al., 2018) involved independent readers at all educational levels, mainly university students. Kong and colleagues (2018) reported that comprehension is superior when reading from paper. Delgado and colleagues (2018) confirmed the inferiority of comprehension when reading expository texts digitally, in particular under a limited time frame. Clinton (2019) again documented superior comprehension for expository texts on paper, for both literal and inferential reading performance. No differences were revealed for narrative texts. The most recent meta-analysis (Furenes et al., 2021) analyzed whether digital books with different types of enhancements can support the story comprehension of children who cannot read independently (mainly aged 4–5 years) without reliance on adults. They showed that children's comprehension of stories was better in printed books than in digital books when the latter included only the voiceover or highlighted print as additional features, and not enhancements that target story content. No differences emerged for book genre (fiction or non-fiction), which did not moderate the effect of medium.

Why does the inferiority of screen emerge as a shared issue across meta-analyses? Several hypotheses have been proposed, two of which are relevant for the present work. The first, offered by studies of independent readers, is the 'shallowing hypothesis' (Annisette & Lafreniere, 2017). It posits that readers process digital text in a superficial and incomplete way, due to their frequent use of digital devices based on rapid and fragmented interactions, for purposes other than learning. The more students are accustomed to quick interactions with digital devices, the less they can use them in challenging tasks that require focused and sustained attention, such as comprehension of expository texts (Delgado et al., 2018). That is, acting as a contextual cue, a digital medium may prime a reader to process the text as if for leisure; in contrast, paper may act as a contextual cue to process a text as if for study and learning (Clinton, 2019).

The second hypothesis posits that digital reading may be affected by the higher cognitive load imposed by limited familiarity with devices and reading on screen, while readers have consolidated experience with traditional reading and reading strategies on paper (Ackerman & Lauterman, 2012). To explain the results with non-independent readers, Furenes and colleagues (2021) also proposed that children's handling of digital devices (e.g., point, click, and swipe) to read enhanced digital books may require additional resources that, given the limited capacity of human information processing system (Mayer, 2009), cannot be allocated to the construction of the meaning of the story.

Note that the three meta-analyses on readers who can read independently are based mainly on studies that involved university or high school students with much accumulated experience of reading on paper. In the very few studies reviewed in the three meta-analyses that involved younger readers, those students were from the higher end of primary school. We have also identified a few other more recent inves-

tigations not included in the meta-analyses. All these studies used comparable printed and digital texts. They differed to some extent in the technical requirements imposed on the digital reading tasks, but they did confirm the screen inferiority effect in fifth graders (Halamish & Elbaz, 2020; Støle et al., 2020) and in fifth and sixth graders (Dahan Golan et al., 2018). Text comprehension on paper outperformed text comprehension on screen even for children who at pre- and post-test reported that they preferred reading digitally or had no clear medium preference (Dahan Golan et al., 2018; Halamish & Elbaz, 2020). These findings in children around the end of primary school might, arguably, be related to their lack of digital skills and experience. But Støle et al. (2020) pointed out that today's 10-year-olds have fundamental digital skills and a lot of experience with digital devices that they also use for learning activities. According to Støle et al. (2020), a more plausible interpretation is that reading disruption caused by scrolling is likely to draw on the limited working memory capacity needed for comprehension (Sanchez &Wiley, 2009).

A recent study also involved first graders with considerable experience with technology at school (Florit et al., 2021). The screen inferiority effect did not emerge for main idea and literal comprehension. It was, though, present for inferential comprehension in children with low word reading skills when considering a composite score for narrative and expository texts. Participants in this study did not show a preference for reading on screen, probably because they did not predominantly use the digital medium for leisure and the traditional medium for learning, and so did not perceive reading on screen as more attractive than reading on paper.

Therefore, it remains an open question worth investigating whether the screen inferiority effect manifests even in beginner readers who can read independently and use digital devices (tablets or computers) not only for leisure but also at school for learning-related activities, and whether they prefer reading on paper or screen.

Individual factors in text comprehension of beginner readers

Traditional literacy skills include individual factors from preschool, before children learn to read, that sustain later reading comprehension on paper (e.g., Kim, 2017; Language and Reading Research Consortium & Chiu, 2018). These traditional literacy skills may be hypothesized to be also involved in reading comprehension on screen (Reading Study Group, 2002). Verbal working memory is a foundational cognitive skill. It is involved in the construction of the textbase level of comprehension, as readers must temporarily store linguistic information while they process and integrate it with new linguistic input. Working memory is also involved in constructing the situation model. The reader needs to maintain and manipulate information when she is integrating sentences and establishing coherence both locally and globally (Kim, 2017). Most studies, indeed, find a relation between working memory and reading comprehension (Ariasi & Mason, 2014; Cain et al., 2004; Carretti et al., 2014; Language and Reading Research Consortium & Logan, 2017; Oakhill & Cain, 2012; Seigneuric & Ehrlich, 2005). However, verbal working memory uniquely accounts for reading comprehension over and above the contribution of higher-level cognitive skills, such as inference skills, in some cross-sectional studies (Cain et

al., 2004) but not in others (Language and Reading Research Consortium & Logan, 2017). Finally, working memory is not a unique longitudinal predictor of reading comprehension once the role of higher-level cognitive skills is considered (Oakhill & Cain, 2012). These mixed results may be explained by the fact that working memory supports the integrative processes involved in higher-level cognitive skills, such as inference skills (Currie & Cain, 2015).

When constructing a coherent mental model of a text, the child is required to generate two types of fundamental inferences. These are text-connecting inferences, which link propositions at a local level, and integrative inferences, which integrate information about the text with prior knowledge of the world (for a review, see Clinton et al., 2020). Research has documented that inference skills between 4 and 6 years predict subsequent reading comprehension (Lepola et al., 2016; Silva & Cain, 2015). There is also evidence that text comprehension can be promoted via training in preschool and primary school that targets inference skills (Bos et al., 2016; Dicataldo et al., 2020). Most of these studies considered narrative texts; inferences generation is also necessary, although more difficult, for expository texts comprehension (Clinton et al., 2020). To the best of our knowledge, studies comparing comprehension of printed and digital texts have considered the role of attention (Delgado & Salmerón, 2021), another foundational cognitive skill, but not verbal working memory and inference skills.

Our study also considered children's basic digital skills, particularly behavioral skills rather than explicit factual knowledge about technology. In mature readers, basic digital skills are defined as the skills that enable them to understand and use the medium where the text is presented, such as a computer or tablet. In addition, while advanced readers are supposed to possess general knowledge about the structures and functionalities of technology, in younger readers or pre-readers, digital skills are more dependent on the medium used (e.g., computer or tablet). Digital natives do not necessarily possess these skills or spontaneously acquire them (Fajardo et al., 2016). Like traditional literacy skills, they develop from the preschool years (Neumann et al., 2016).

Studies on preschool children have documented possible advantages of being exposed to digital texts (e.g., digital storybooks) in addition to traditional texts in promoting the development of some literacy skills in printed text comprehension (Lauricella et al., 2014; Takacs et al., 2015). Yet, when considering digital texts, basic digital skills are crucial, for example, the ability to use a mouse, to press buttons to move back and forward, to click, and to scroll up and down. With readers in the fifth year of primary school, Fajardo and colleagues (2016) have shown that these basic skills play an important role in the comprehension of digital texts, independently of the readers' comprehension of printed texts.

Finally, given our interest in beginner readers, we examined word reading skills as a control variable that is fundamental for printed and digital text comprehension when children are at the end of the first grade and have just learned to read (Florit et al., 2021; Kim, 2017; Tobia & Bonifacci, 2015).

The study: research questions and hypotheses

This longitudinal study aimed to extend current research on children's reading from paper and screen in the crucial transition from preschool to the first grade. Specifically, relevant precursors such as working memory, inference skills, and basic digital skills were measured at the end of preschool (T1); digital and printed text comprehension and reading preferences, and word reading skills as a control variable were measured at the end of the first grade (T2). Comparable digital and printed texts included narrative and expository (i.e., descriptive) texts typically used from the first grade. The study was guided by two main research questions (RQ):

(1) Do reading medium (paper vs. screen) and text genre (narrative vs. descriptive) differentiate text comprehension in children at the end of the first year of primary school (T2)? Do beginner readers prefer reading on paper or on a computer screen?

(2) Do working memory, inference skills, and basic digital skills at the end of preschool (T1) predict text comprehension at the end of the first year of primary school (T2), considering both text genre and reading medium, and controlling for word reading skills? If differences emerge at T2 for comprehension in relation to reading medium and text genre, are they predicted by the precursors measured at T1?

For RQ1 we hypothesized a difference in text comprehension related to reading medium. That is, we expected lower comprehension for reading from the computer screen than from paper, since a higher cognitive load is required of children for digital behaviors, such as scrolling for reading text and questions and pressing buttons to move back and forward across pages for answering questions (Neumann et al., 2016; Støle et al., 2020). Moreover, concerning text genre, we hypothesized greater comprehension of narrative than descriptive texts because they are more familiar to beginner readers who have experienced them in preschool and at home during storybook reading (Furenes et al., 2021). Furthermore, based on recent meta-analyses, we hypothesized an interaction effect of reading medium and text genre. Specifically, we expected superior text comprehension when children read descriptive texts, but not narrative texts, on paper, as expository texts require a deeper level of content processing than narrative texts (Clinton, 2019; Delgado et al., 2018). We expected beginner readers to report a clear preference for reading on screen over reading on paper (Dahan Golan et al., 2018). As digital natives, indeed, their experience with digital devices and on-screen activities must be more pleasant than the one with printed materials.

For RQ2, we hypothesized that comprehension of texts presented on paper and screen at T2 would be predicted by inference skills at T1, after controlling for word reading skills. Predictions were less clear for working memory since mixed findings have been reported about its contribution to text comprehension on paper. However, we did not expect working memory at Time 1 to predict comprehension of texts presented on paper and screen at T2, because—as in a previous longitudinal study (Oakhill & Cain, 2012) — we included higher-level cognitive skills (i.e., inference skills) among predictors. Finally, we expected that basic digital skills would contribute to the comprehension of texts presented on screen but not on paper (Fajardo et al., 2016). Finally, we hypothesized that basic digital skills, but not working memory and

inference skills, would predict the expected difference in text comprehension, due to reading medium, after controlling for word reading skills.

Method

Design and participants

At T1, 72 Italian children participated, and one year later, at T2, 63 out of the 72 participants were involved. The participants in this study were included in a larger project on medium effects on text comprehension in beginner readers. However, the hypotheses, measures, analyses, and results presented in this paper are unique to this study. The children participated with their own verbal assent and their parents' written consent. The mean age of the 63 children (F = 35) was 5.8 years (*SD* = 0.3) at T1 and 6.8 (*SD* = 0.3) years at T2. The 12.5% attrition between T1 and T2 was due to their families having relocated, absence on the day of the assessment session, and lack of written consent from parents. Of the participating children, 70% had Italian parents, 8% had one Italian parent, and 22% had immigrant parents. According to the reports of preschool and primary school teachers, none of the 63 participants had been referred to the National Health Services for cognitive impairments or language difficulties in Italian. Average performance scores on a standardized measure of receptive language, the Italian version of the Peabody Picture Vocabulary Test (PPVT; Stella et al., 2000), collected at T1 (*M* = 88.08, *DS* = 13.64) and nine months later during the first year of school (*M* = 95.86, *DS* = 12.39), also showed that the average performance was within the age-appropriate range according to available norms (*M* = 100, *SD* = 15). At the same two time points, a measure of general executive functioning was collected using the Inhibition subtest from the Italian version of the standardized assessment NEPSY-II (Urgesi et al., 2011). Performance in the Inhibition subtest, both at T1 (*M* = 8.63, *DS* = 2.49) and nine months later (*M* = 10.47, *DS* = 2.49), was within the age-appropriate range according to available norms (*M* = 10, *SD* = 3).

At T1, parents completed questionnaires on demographic information and data on the home environment. The average educational level of mothers and fathers was high school (*M* = 2.28, *SD* = 0.99, range 1–5 where 0 = primary school and 5 = master level/PhD). The annual income of the families was near the average Italian family income (*M* = 1.68, *SD* = 1.01, range 0–4 where 0 = far below the mean and 4 = far above the mean; ISTAT, 2009). Taken together, these results suggest that all children shared a homogeneous middle/working-class social background. In addition, concerning the availability of digital devices and traditional and digital books, parents reported that 64–65% of the children used smartphones and tablets at home, and 40% of children used laptops or computers. Families had on average 21–40 traditional books for children (M = 2.44, SD = 1.32, range 1–5 where 0 = none and 5 = more than 80 books). Most of the families have few or no digital books for children (M = 0.18, SD = 0.38, range 0–1 where 0 = none and 5 = more than 80 books).

According to their teachers' reports, the children attended 11 classes from 6 schools in the same school district, one where technology was used for educational activities

2/4 hours per month. In Italy, the national curriculum for teaching digital skills in public primary schools requires children to spend 1 h per week using computers.

Texts

Four texts about animals were used, two narrative and two descriptive (expository). The four texts were used in a previous study (Florit et al., 2021) and were partly modified to be used in a wider project on text comprehension on paper, computer, and tablet. Narrative and descriptive texts were devised as representative of the text genres used in first grade, and therefore appropriate for identifying possible differences across mediums (Delgado et al., 2018). The two narrative texts introduced a short story about an animal (a teddy bear and a hedgehog). The two descriptive texts provided information about an animal's physical characteristics and behavior (tortoise and parrot). Texts were 101–106 words long, and their readability (Gulpease Index, Lucisano 1992) ranged from 81 to 85, showing that the texts were appropriate for primary school children (Piemontese, 1996). Examples of the texts are reported in the online supplementary information.

Measures at T1 (end of preschool)

Working memory. This was measured using a backward word span task (Florit et al., 2014). The task consisted of six series of word lists that had no semantic or phonological relations, and with an increasing number of items (list length ranged from 2 to 7 words; four series for each list length). Children were presented with the lists of words and asked to repeat them in reverse order. The test stopped when the child failed to repeat three of four series of the same length. One point was credited for each series correctly repeated (possible range 0–24). The reliability for the task was 0.68 (McDonald's omega).

Inference skills. An inferential task, which did not involve complex discourse comprehension, was used (Florit et al., 2014; Dicataldo et al., 2020). The task consisted of ten episodes, each comprising three short sentences describing common and familiar events, and two inferential questions (one text-connecting inference and one integrative inference). Answers were evaluated on a 0–2 point scale for a maximum score of 40. The reliability for the inferential task was 0.92 (McDonald's omega).

Basic digital skills. Following a checklist inspired by the work of Javorsky (2014), the children were asked 29 questions, mainly performance, to measure basic digital skills. The skills were related to the use of computers and laptops, the digital devices usually available in Italian primary schools. The checklist was piloted on a small group of 5 preschoolers who were not involved in the present investigation in order to confirm that the requests were appropriate to the technical experience of very young children and to refine the scoring system. Pilot work led to minor modifications. In the final version, the questions asked included: (a) mechanical skills concerning the use of the various components of the device (e.g., "Can you show me how you make the computer work?"), (b) navigation skills regarding access and navigation within and across pages of digital environments (e.g., "How can we go back to the first page"?), and (c) symbolic skills related to the knowledge of the main symbols of

digital environments (e.g., “Show me the icon to play with letters”). In order to assess basic digital skills, a laptop with a touchpad and a mouse was used, and a Google-like environment was developed as a situated assessment for the present study. Children were first asked performance questions concerning their mechanical skills. Later, the navigation and symbolic skills were assessed by asking children to click on Internet Icons available on the screen to find web pages with stories and pictures. Specifically, children were required to click on one of four common Internet icons (i.e., Internet Explorer, Chrome, Firefox, and Safari) to follow an established path in accessing six web pages. These web pages constituted the Google-like environment. The icons and webpages were in fact offline and stored locally. Navigation skills were assessed by asking children to move within and across the web pages, and symbolic skills were evaluated by considering symbols presented on the web pages. At the end of the task, the child received a coloring page (e.g., a drawing of an animal/object that he/she had previously seen on the web pages) as a gift. Answers were coded 0–2 according to accuracy and completeness. A total score was computed. The reliability for this task was 0.72 (McDonald’s omega). For the analysis, 21 of the 29 items were retained since eight items of the symbolic skills subset tap-on skills were also involved in the linear printed text comprehension (e.g., "Show me where to start to read the text").

Measures at T2 (end of the first grade)

Text comprehension. Based on studies involving both older (Singer & Alexander, 2017) and same-age students (Florit et al., 2021), text comprehension was measured using seven multiple-choice questions with four alternative answers for each text. These were: one question on the main idea, three questions on literal comprehension, and three questions on inferential comprehension. Examples of questions are reported in the online supplementary information. The questions were devised by the first author and had been used in a previous study (Florit et al., 2021). We relied only on verbal questions instead of verbal and pictorial questions for two main reasons: (a) to maximize the likelihood of comparable presentations of the comprehension questions across mediums and (b) because, according to the language arts teachers, verbal questions were also commonly used in first grade for the assessment of text comprehension. Each correct answer was awarded 1 point, and a total score was computed (the maximum score for each text was 7). The reliability of texts ranged from 0.68 to 0.71 (McDonald’s omega).

Medium preference questions (screen text vs. printed text). Before and after reading all four texts, participants completed a preference question asking whether they preferred reading a text on paper or reading it on screen.

Word reading skills (control variable). The word reading and non-word reading tasks used came from the Test Battery for the Evaluation of Developmental Dyslexia and Dysorthography (Sartori et al., 2007). The children were asked to read 112 words and 48 non-words as accurately and quickly as possible. Word reading and non-word reading accuracy (number of correct answers/number of items) and fluency (number of syllables read per second) were computed. Z-scores were derived for accuracy and fluency, and a composite score of word reading was calculated and used in the analyses. The reliability of the accuracy for words and non-words in the present sample

was 0.93 and 0.85, respectively (McDonald's omega). Test-retest reliability reported in the manual for reading fluency is 0.80.

Procedure

The measures were administered in one session held at the end of the last year of preschool (during May and June) at T1 and five sessions, approximately one week apart, one year later at T2, as part of the broader project. Each session was 40–45 min long. T1 measures were administered individually in a quiet room of the school and in a counterbalanced order. In the first session at T2, in a quiet room of the primary school, students were individually asked the preference question at pre-test and then given the word and non-word reading tasks. At T2, in sessions two to five, the reading comprehension tasks were group-administered in the classroom and the computer lab. Each student read four texts, two on paper (one narrative and one descriptive) and two on a computer screen (one narrative and one descriptive), and responded to four sets of comprehension questions, two on paper and two on a computer screen. The order of text presentation was randomized by medium and genre. Each text was presented on a single page, and comprehension questions were asked and answered in the same medium as the one in which the text was presented; that is, the children had to tick or click the correct answer when reading on paper or computer screen, respectively. The screen resolution chosen required the children to use arrows to go down on the page to read the last sentence of each text. They also had to click on the arrow to go to the next page and to read the last comprehension question. All the children used the mouse autonomously to perform the digital text comprehension tasks. The children could access texts while answering questions in both mediums. They read the four texts at their own pace since the task had no time limit. The font size of all texts and questions was 16-point Cambria, the same as in textbooks with uppercase block letters that teachers used. Double spaced A4 sheets were used to present the printed texts. Digital texts appeared on a 17″ computer screen by means of the open-source software LimeSurvey; the resolution was 1280×1024 pixels. At the end of the fifth session, the children answered the medium preference question at post-test.

Data analysis

First, descriptive statistics were computed in terms of means, standard deviations, skewness and kurtosis, and correlations were computed for all continuous variables in the study. For reading medium preference, mean percentages were computed at pre-and post-test. Second, to address RQ1, linear mixed models were used to test the effects of medium (paper vs. digital), text genre (narrative vs. descriptive), and their interaction on text comprehension. If a significant interaction term was found, a simple slope analysis was performed, and data were plotted. A binomial test was also computed to test differences in reading medium preference at pre- and post-test. Third, to address RQ2, linear mixed models were run to test for (a) the contribution of working memory, inference skills, and basic digital skills at T1 to text comprehension at T2, and (b) the interaction effect between basic digital skills and medium to text

Table 1 Descriptive statistics of the examined variables (N = 63)

	M	*SD*	*Min*	*Max*	*Skewness*	*Kurtosis*
Working memory T1	3.78	1.67	0	8	-0.33	0.29
Inference skills T1	18.84	6.65	7	35	0.25	-0.62
Basic digital skills T1	20.38	6.99	7	35	0	-0.83
Word reading skills T2[a]	0	0.87	-3.03	1.89	-0.52	0.84
Printed text comprehension - Narrative T2	5.38	1.41	2	7	-0.75	-0.44
Printed text comprehension - Descriptive T2	4.73	1.72	1	7	-0.18	-1.15
Digital text comprehension - Narrative T2	4.95	1.57	1	7	-0.49	-0.69
Digital text comprehension - Descriptive T2	5.21	1.36	2	7	-0.64	-0.24

Note. T1 = end of preschool; T2 = end of the first year; [a] Composite score (Z scores) of accuracy and fluency

comprehension at T2. These linear mixed models controlled for word reading skills at T2, medium, and text genre. Mixed models were used to take into account the nested structure of the data, since observations were nested in individuals (i.e., repeated measures of text comprehension across mediums and text genre) who were nested in classes. Estimation problems prevented the fit of planned models with both random intercepts and slopes. As suggested by Barr et al. (2013), non-converging models were dealt with by progressively simplifying the random effects structure until convergence was reached, resulting in our case in a random-intercept-only model.

Analyses were performed with R (R Development Core Team, 2021) using the lme4 package (Bates et al., 2015) to test generalized and linear mixed models and the lmerTest (Kuznetsova et al., 2014) to obtain standard errors for linear mixed models. The percentage of variance explained by each model was computed following the approach of Nakagawa and colleagues (2017). It included both marginal R^2 and conditional R^2, which refer, respectively, to the variance explained by the fixed effects and the global variance of random and fixed effects. Plots were built with the ggplot2 package (Wickham, 2009).

Results

Descriptive statistics of the continuous variables and correlations among them are presented in Tables 1 and 2, respectively.

The data did not deviate substantially from normality for skewness and kurtosis, which were within the acceptable range (Tabachnick & Fidell, 2013). Performances in the working memory task were in line with previous studies (Florit et al., 2014). Performances on the tests of inference skills, basic digital skills, and text comprehension covered almost the whole range of possible scores. They did not suffer from either floor or ceiling effects. Table 1 reports the composite scores (Z scores of accuracy and fluency) of word reading skills. The average performances for measures of reading accuracy ($M = 0.83$, $DS = 0.08$; $M = 0.91$, $DS = 0.14$ for words and non-words) and fluency ($M = 0.65$, $DS = 0.24$; $M = 0.70$, $DS = 0.31$ for words and non-words) were within the age-appropriate range according to available norms (Sartori et al., 2007). Zero-order correlations, which range from low to large, were reported for descriptive

Table 2 Zero-order correlations between the examined variables (N = 63)

	1	2	3	4	5	6	7	8
1. Working memory T1	-							
2. Inference skills T1	0.26*	-						
3. Basic digital skills T1	0.34**	0.46***	-					
4. Word reading skills T2[a]	0.16	0.00	0.16	-				
5. Printed text comprehension - Narrative T2	0.32*	0.32**	0.13	0.28*	-			
6. Printed text comprehension - Descriptive T2	0.32*	0.23	0.20	0.29*	0.51***	-		
7. Digital text comprehension - Narrative T2	0.43***	0.37**	0.44***	0.37**	0.66***	0.66***	-	
8. Digital text comprehension - Descriptive T2	0.28*	0.24	0.27*	0.37**	0.50***	0.44***	0.54***	-

Note. T1 = end of preschool; T2 = end of the first year; [a] Composite score (Z scores) of accuracy and fluency

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

purposes only since Pearson's correlations do not consider the nested nature of the data.

At pre-test, 48% of children reported that they preferred reading on paper and 52% on screen. At post-test, 22% of children said they preferred reading on paper and 78% on screen.

RQ1: comprehension of narrative and descriptive texts from paper and screen and reading medium preferences

The first linear mixed model found the non-significant main effects of both medium (b = 0.01, 95% CI -0.11–0.14, SE = 0.06, $t(245) = 0.19$, $p = .85$) and text genre (b = -0.10, 95% CI -0.23 – 0.03 SE = 0.06, $t(245) = -1.54$, $p = .12$), but their significant interaction on text comprehension (b = 0.23, 95% CI 0.10–0.35, SE = 0.06, $t(245) = 3.52$, $p < .001$). Figure 1 presents the effects of the interaction effect, showing that narrative texts are associated with better text comprehension than descriptive texts in the case of paper (b = -0.65, 95% CI -1.04 – -0.26, SE = 0.20, $t(121) = 3.30$, $p = .001$) but not in the case of the digital medium (b = 0.25, 95% CI -0.10–0.60, SE = 0.18, $t(121) = 1.43$, $p = .15$).

The Binomial tests showed that the children had a clear preference for reading on screen at post-test ($p = .001$) but no clear medium preference at pre-test ($p = .801$).

RQ2: predictors of narrative and descriptive text comprehension on paper and screen

Table 3 presents the results of the second linear mixed model.

Working memory and inference skills at T1 were significant unique and positive predictors of text comprehension at T2, after controlling for medium, text genre, and word reading skills at T2. The latter, considered as a control variable, was also a unique significant predictor of text comprehension at T2. The interaction between basic digital skills and medium, as hypothesized, was also significant: digital skills

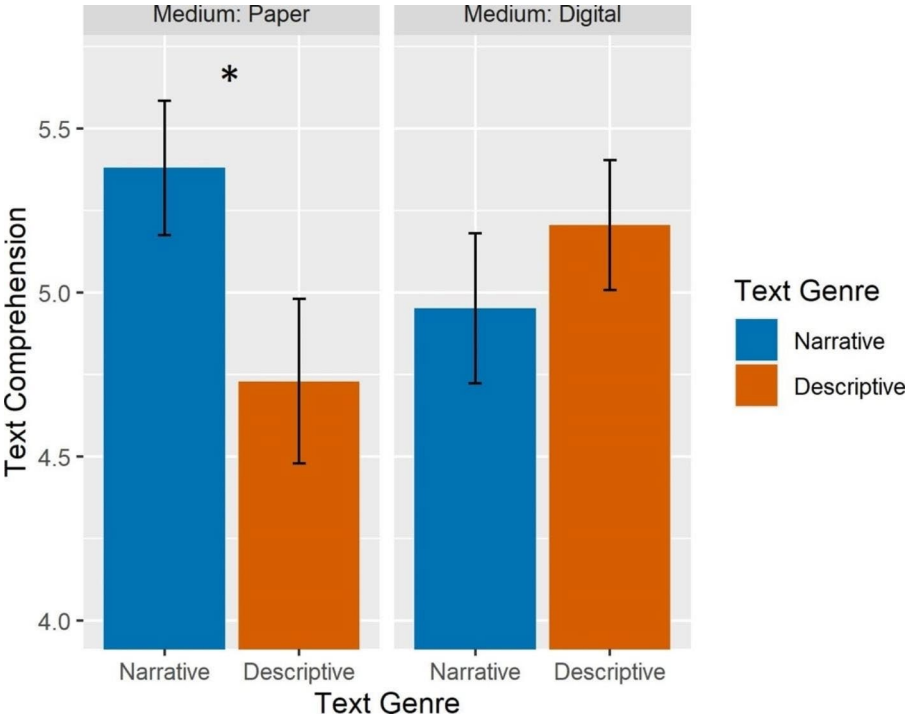

Fig. 1 Interaction of medium and text genre on text comprehension

contributed to the comprehension of texts presented on screen but not on paper. Figure 2 shows the simple slope analysis to interpret the moderation effect.

Basic digital skills showed a positive, marginally significant unique longitudinal effect on digital text comprehension (b = 0.04, SE = 0.02, $t = 1.77$, $p = .08$), but not on printed text comprehension (b = 0.00, SE = 0.02, $t = 0.01$, $p = 1.00$).

Discussion

This study sought to extend current knowledge about text comprehension in relation to reading medium and text genre. To our knowledge, it is the first study with a longitudinal design involving children in the crucial transition from preschool to primary school. We focused on the comprehension of comparable linear texts in first graders who have just learned to read independently. We followed these children from the end of preschool as we were interested in fundamental and high-level cognitive precursors of text comprehension, which have long been the subject of research on the comprehension of linear printed texts (e.g., Ariasi & Mason 2014; Kim, 2017; Oakhill & Cain, 2012). We also considered the precursor of basic digital skills, as it has been shown that it is required to effectively read from the screen of an electronic device (Fajardo et al., 2016).

Table 3 Results of linear mixed models to test the effects of working memory, inference skills, basic digital skills at T1, and the interaction of digital skills at T1 and medium on text comprehension at T2

	Text Comprehension				
Predictors	*b*	*SE*	*CI*	*t*(241)	*p*
(Intercept)	4.51	0.79	2.96–6.06	5.71	<0.001
Medium	-0.76	0.41	-1.56–0.04	-1.86	0.06
Text Genre	-0.20	0.13	-0.46–0.06	-1.51	0.13
Word Reading Skills T2	0.47	0.14	0.20–0.74	3.37	0.001
Working Memory T1	0.15	0.07	0.01–0.30	2.08	0.04
Inference Skills T1	0.05	0.02	0.01–0.09	2.57	0.01
Basic Digital Skills T1	-0.04	0.03	-0.11–0.03	-1.11	0.27
Digital Skills T1*Medium	0.04	0.02	0.00–0.08	2.03	0.04
Random Effects					
σ^2	1.09				
ICC	0.43				
$N_{Participants}$	63				
$N_{Classes}$	11				
Observations	252				
Marginal R^2 / Conditional R^2	0.221 / 0.553				

Note. T1 = end of preschool; T2 = end of the first year; σ^2 = variance of residuals; ICC = Intra class correlation

Our first research question asked whether reading medium (paper vs. screen) and text genre (narrative vs. descriptive) differentiate text comprehension in beginner readers at the end of the first grade. Our findings did not confirm our hypotheses, as the two main effects of reading medium and text genre were not significant. In contrast, a hypothesized interaction between reading medium and text genre did emerge; the narrative text was comprehended better than the descriptive text when reading on paper. The lack of the main effect of the reading medium does not accord with the outcomes of the most recent meta-analyses (Clinton, 2019; Delgado et al., 2018; Kong et al., 2018), which supported a screen inferiority effect in independent readers. In addition, our results for beginner readers cannot be explained by reference to the shallowing hypothesis (Annisette & Lafreniere, 2017). This hypothesis, which was adopted to explain the results of previous meta-analytic research, proposes that the medium acts as a contextual cue for text processing due to the different uses of paper and digital mediums.

Previous comparative studies on reading medium have involved students at the secondary level (Clinton, 2019; Delgado et al., 2018) and, even when primary school students were involved in recent studies (Dahan Golan et al., 2018; Halamish & Elbaz, 2020; Støle et al., 2020), they were in the higher grades. Therefore, recent work relied on older independent readers with much accumulated experience of reading on paper mainly for study and learning and of using the digital medium for leisure. According to our data, participants in this study used technology at home (i.e., they mainly use smartphones and tablets) probably for leisure and entertainment (e.g., for listening to music, watching videos, and playing with videogames; Rideout & Robb, 2020). They were also exposed to pleasant activities involving the paper medium, such as shared book reading. However, they had much less accumulated experience both of reading

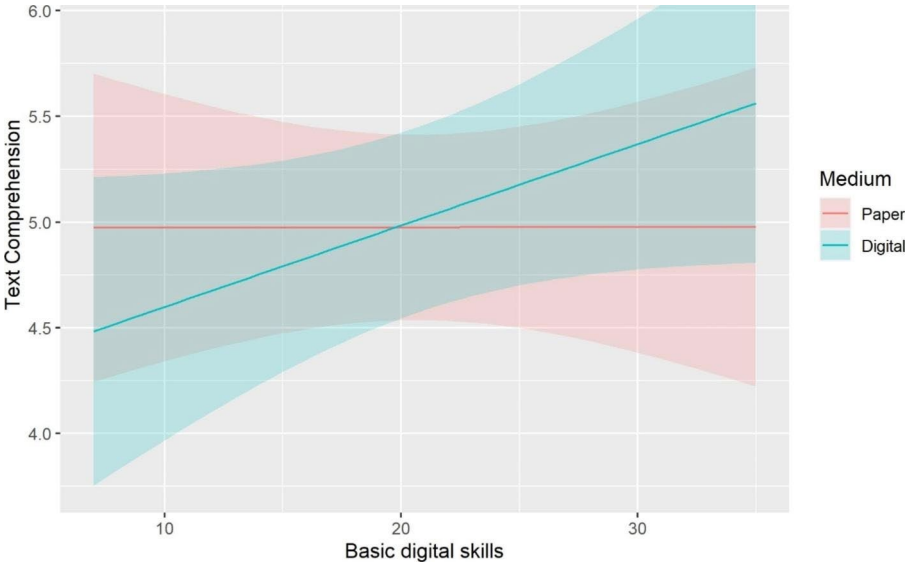

Fig. 2 Simple slope analysis of the interaction between medium and basic digital skills on text comprehension

on paper mainly for study and learning and of using the digital medium for leisure. These differences in the use of the two mediums between older and younger students may limit the medium effect. That is differences in exposure both prevent the paper medium acting as a contextual cue to processing a text for study and learning, and the digital medium acting as a contextual cue to processing a text for leisure.

A second hypothesis to explain the disadvantage of text comprehension on screen considers the higher cognitive load imposed by the students' lower level of familiarity with reading on screen than on paper and with using digital devices (Ackerman & Lauterman, 2012; Furenes et al., 2021). We found few differences in the children's reading strategies between reading on paper and screen. As discussed above, this can be explained by their limited experience as independent readers compared with older students who have learned how to read from paper. A few of the children returned to the text while responding to the comprehension questions when reading texts on paper but not on screen. This strategy seems to be related to the children's literacy experience at school rather than to basic digital skills (i.e., navigation skills). The teachers habitually advised children to go back to the text to find information when answering comprehension questions, rather than relying on memory. When doing so, the teachers were mainly using printed texts. Therefore, some children adopted this strategy, at least to some extent, while reading on paper but not on screen. The use of this strategy is linked to the use of paper mainly for study and learning.

Our results do not align with existing evidence of a disadvantage for the comprehension of enhanced digital books vs. printed books when the former included few enhancements and required additional resources to point, click, and swipe (Furenes et al., 2021). It is difficult to compare the results of the present study with those of Furenes and colleagues (2021), who focused on the comprehension of books in non-

independent readers. Nevertheless, we may speculate that the reason a disadvantage for digital texts did not emerge in our study is that the children faced less cognitively demanding digital texts than they would meet with enhanced digital books. Indeed, results from the longitudinal analysis undertaken in the present study support the critical role of digital skills.

The results on the interactive effect of reading medium and text genre showed that text genre influences text comprehension only when the traditional reading medium is considered. According to parents' reports, children have limited experience with technology at school and digital books at home, but much accumulated experience of storybook reading at home. We can also speculate that this outcome is mainly due to the children's greater familiarity with independent reading of narrative text from paper at school, which is what they are mainly asked to do in the first grade as soon as they have learned to read (Diakidoy et al., 2005). Furenes and colleagues (2021) found no differences when considering book genre (fictional or non-fictional) as a moderator of medium effect. This different result may be due to the fact that the most common book genre in the study of Furenes and colleagues (2021) was fiction for a younger age group.

Concerning reading preferences, our participants showed a preference for reading on screen at post-test but not at pre-test. This result can be explained by the fact that children predominantly use the traditional medium for reading at school while families have no or few digital books for children at home. We may therefore speculate that the participants perceived reading on screen as more attractive than reading on paper because for them digital texts represented a relatively novel experience in the school context.

Our second research question addressed the role of traditional literacy skills (working memory and inference skills) and digital skills (basic digital skills) in text comprehension in the two mediums. Our hypotheses about longitudinal predictors were partially confirmed. Specifically, digital skills assessed at the end of preschool were a significant predictor of digital text comprehension one year later, over and above cognitive predictors. The higher were the children's basic digital skills to use a laptop and navigate within a digital context in preschool, the higher was their comprehension of digital texts at the end of first grade. This finding is aligned with those showing the importance of these skills as a resource when reading online (Fajardo et al., 2016; Neumann et al., 2016). They are also particularly important in the youngest readers tackling linear texts.

In addition, our longitudinal models show that inference skills assessed at the end of preschool accounted for digital and printed text comprehension one year later, after controlling for word reading skills. The latter, moreover, was confirmed as a significant predictor of beginner readers' text comprehension in both mediums (Florit et al., 2021) and both text genres. Contrary to our expectations, working memory was also a unique longitudinal predictor of printed and digital text comprehension, even if higher-order inference skills were considered.

Our results extend to beginner readers the research that has explored the roles played by foundational cognitive and language component skills in the comprehension of printed and digital texts in older independent readers (Delgado & Salmerón, 2021) and the comprehension of printed and digital books in younger preschoolers

(Lauricella et al., 2014). We provide empirical evidence for a model of linear digital text comprehension in which basic digital skills are a specific component, along with word reading, working memory, and inference skills, which are components common to both printed and digital text comprehension. We considered basic digital skills related to computer and laptop use because they are the most commonly used digital devices in primary schools, at least in Italy. As shown by parents' responses to the questionnaire about the home environment, children at the end of preschool are more familiar at home with other digital devices, such as tablets and/or smartphones (cfr. Rideout & Robb, 2020; Smahel et al., 2020). In younger readers or pre-readers, digital skills depend more on the medium used. However, all items in the checklist on digital skills, except the subset assessing mechanical skills use, enable children to understand and use both computer/laptop and tablet as mediums through which a text may be presented. This claim is supported by the fact that the checklist on computer/laptop use correlated significantly ($r = .58$) with a second checklist with similar items but related to the use of a tablet, which was administered as part of the wider project on text comprehension in beginner readers. The findings of the present study, though, do not support a test of whether working memory and inference skills can predict potential differences in text comprehension across mediums in beginner readers.

Educational implications

This study has significant educational implications. First, our results underline the importance of acquiring basic digital skills to support linear digital text comprehension. Child-adult interactions with digital devices and digital texts may sustain the development of emergent digital literacy (Hisrich & Blanchard, 2009). Children start interacting with digital texts using electronic storybooks whose technological enhancements make the reading experience qualitatively different from their experience with traditional paper books. For instance, Lauricella and colleagues (2014) found that parents focused more on the mechanics of the device when reading digital than printed books when interacting with their four-year-old children. Thus, child-adult interactions with digital texts should be regarded as additional contextual factors that may promote basic digital skills acquisition. As shown by the descriptive data of the present study, preschoolers start on-screen activities using laptops and computers that are present at home. These activities require some adult guidance and may also support basic digital skills acquisition. Notably, the digital skills considered by our checklist, especially navigational skills, are also needed for interacting with digital devices other than laptops or computers, such as smartphones and tablets, to which children are also exposed. As research has indicated, digital natives do not necessarily have the digital skills to benefit fully from digital reading (Fajardo et al., 2016; Neumann et al., 2016). It is, therefore, crucial to provide children from an early age with a range of ways of making sense of reading in digital environments. These opportunities should also help beginner readers to develop awareness of what digital reading requires, as distinct from traditional paper reading.

Second, our results show that the involvement of working memory and inference skills in the construction of meaning in texts is independent of the medium through which the text is presented. It has been shown that adults' mediation during print

book reading influences children's text comprehension more effectively than the enhancements provided by digital books read by children independently, particularly when the enhancements are not related to the content of the book (Furenes et al., 2021). However, the superiority of paper over digital books in stimulating text comprehension disappears when adult mediation is the same between the mediums and when the enhancements in digital books are content-related (Furenes et al., 2021). There is also evidence that parents can adjust their interactions based on the characteristics of the medium and their children's skills to facilitate meaning construction (Lauricella et al., 2014). In other words, the quality of parent-child social interactions is crucial to the promotion of children's text comprehension regardless of the medium through which the book is presented. In sum, previous evidence suggests that, when the digital books selected are unlikely to cause children's distraction or increase cognitive load, child-adult literacy activities in the digital medium may help to promote the acquisition of working memory and inference skills, as is the case with literacy activities in the traditional medium.

Limitations

First, the sample is small, although the attrition from T1 and T2 is acceptable. More participants would allow for more complex statistical analyses and more solid data. Second, only one year elapsed from T1 and T2, so the longitudinal nature of the study is somewhat limited, although we did include a crucial transitional phase examining the role of the precursors of text comprehension in readers who have just learned to read. Future studies should also cover a broad age range to further test our interpretations concerning the differences in the use of the two mediums between students at the lower and higher end of primary school. This will make it possible to further clarify how differences in the use of mediums relate to the medium effect on text comprehension. Third, while we considered some of the critical precursors, other components are also involved in children's text comprehension. Future research that includes additional components will illuminate any differences in reading comprehension related to reading medium and text genre. In this regard, whereas we included traditional measures of word reading skills as a control variable, we did not collect measures of word reading in both mediums. Studies of readers who have mastered word reading skills, mainly undergraduates, as in Clinton (2019; for a study on adolescents, see Ronconi et al., 2022), found no differences in reading times between the two mediums. Longer times, though, were found for reading on screen than on paper in children at the end of primary school (Kerr & Symons, 2006; but see Lenhard et al., 2017). In these studies, text comprehension performance was better on paper than on screen. These results, therefore, indicate that reading from paper is more efficient than reading from a screen. Traditional measures of beginner readers' word reading skills have previously been shown to play a stronger role in text comprehension on screen than on paper at the literal and inferential level of text comprehension (Florit et al., 2021). Based on this evidence, future research should assess word reading accuracy and fluency in both mediums, in order to deepen our understanding of the potential differences in reading between the mediums. Finally, we observed few differences in reading strategies (i.e., metacognitive strategies such

as going back to the text while answering comprehension questions) between reading on paper and screen. However, meta-analytic studies on university students have suggested that reading medium effects may be related to differences at the metacognitive level (e.g., Clinton 2019). Therefore, more systematic observations on a larger sample are required if we are to form firm conclusions on the existence of such differences in beginner readers.

Fourth, we considered only one digital device, the computer, as children had some familiarity with computers and laptops in primary school. Future research may also compare types of digital device used for reading on screen, as differences could emerge in relation to their affordances (Salmerón et al., 2021). Fifth, because we considered comparable linear printed and digital texts appropriate for beginner readers, our results cannot be generalized to the types of non-linear, complex texts that characterize multimedia environments.

Sixth, because we used only a few texts, and they were relatively brief (as was deemed appropriate to the children's grade level), we used only a limited number of questions to assess text comprehension.

Conclusions

Despite these limitations, the present longitudinal study extends current research by examining the role of traditional and digital literacy skills in the comprehension of printed and digital texts, both narrative and expository texts, in the crucial transition from preschool to the first grade. The study shows that in beginner readers, at the end of the first grade, there was no evident inferiority for reading from a screen, at least when linear printed and digital texts were considered. Word reading, working memory, and inference skills were common precursors of text comprehension in the two mediums, while basic digital skills were specific precursors of digital text comprehension. Digital skills should be considered in comprehensive models of emergent digital literacy.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s11145-022-10327-w.

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Author contributions Elena Florit: Conceptualization, Methodology, Analysis, Writing-Original Draft. Pietro De Carli: Analysis, Writing-Original Draft. Antonio Rodà: Methodology. Samantha Domenicale: Data Collection. Lucia Mason: Conceptualization, Writing-Original Draft, Supervision.

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Statements and declarations

The authors declare no conflict of interest.

The study was approved by the ethics committee of Psychological Research Area of the University of Padova (ethical approval code: 7F35AB627AB88DEF551318A3539E38EE).

Children participated with their own verbal assent and their parents' written consent.

The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy.

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