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Which executive functions affect text comprehension and writing in paper and digital mode? An investigation in primary school children

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ABSTRACT

The scientific literature supports the hypothesis of a disadvantage in students' performances when learning tasks are conducted in the digital mode in comparison to the paper one. Some studies suggest the need of investigating the role of individual cognitive functioning in digital reading and writing with special attention to those cognitive processes, such as Executive Functions (EF), which are acknowledged to control and affect learning and school adaptation. The present study aimed to: 1) investigate the differences in performances between paper and digital modalities in text reading and text writing in primary grade students; 2) analyse whether EF predict performances in paper and digital modalities; 3) explore whether any differences between paper and digital text comprehension or writing can be differently explained by EF depending on the children's learning performances. 175 typically developing Grades 3–5 students performed text comprehension and text writing tasks on computer and on paper and were assessed with EF tasks tapping inhibitory control, working memory and cognitive flexibility. The results showed no performance differences between digital and paper tasks at the group level apart from a higher text length in the digital than paper mode. However, children with low performances at the comprehension and writing tasks benefited more from the digital than the paper mode, in comparison to high performers that showed the opposite pattern. Additionally, low performers scored worse than high performers in most of the EF tasks. Lastly, working memory explained the digital-paper difference in text comprehension among low comprehenders as well as cognitive flexibility explained the difference in level of narrative complexity and number of words among low writers.

The results suggest the benefit of the digital mode for low readers and writers and highlight the role of the main components of EF in reading and writing in both paper and digital modes in primary school.

1. Introduction

Over the last few decades, the number of children who use internet-connected technological devices at school and at home on a daily basis has considerably increased, reaching exponential levels following the health emergency from Covid-19 (Fernandes et al.,

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2020). It is of paramount importance to consider the differences between digital and paper learning performance (Delgado et al., 2018) as digital media could require a higher cognitive control in comparison to traditional paper-and-pencil learning (Ackerman & Lauterman, 2012). The processes underlying the regulation of our mental functions refer to the construct of Executive Functions (EF), a family of high-level cognitive processes that allow adaptation to novel everyday situations and are involved in new tasks, in challenging situations and in goal-directed activities (Diamond, 2013). EF are involved in several learning tasks and thus they predict learning outcomes across ages and populations (Bausela-Herreras et al., 2019; Cortés Pascual et al., 2019). Particularly, text comprehension and text writing are two fundamental skills for learning, considered day life tasks in primary school, and requiring high-level cognitive control (Follmer, 2018; Kellogg, 2022).

Despite the recent increase of digital tools in education, studies on school-aged children tended to focus on investigating EF contribution to reading and writing in the paper mode, but they neglected the digital one. To our knowledge, there is only one recent study that investigated how working memory skills could predict both printed and digital text comprehension in preschoolers at the end of the first grade (Florit et al., 2022). Indeed, this work found that there is a significant relationship between the skills assessed in preschool and the ones assessed at the end of first grade in both conditions. To contribute to our understanding of the cognitive processes underpinning digital reading and writing, this study had the objective of investigating which EF is related to text comprehension and text writing in both modes (digital and paper). Furthermore, it also showed which EF related to performance differences between the two modalities in primary grade students and how.

1.1. Framework of text comprehension and text writing

Among the learning skills, comprehending what has been read and being able to write opinions and thoughts are two central abilities to communicate with the environment in the actual society (Allen et al., 2014).

Text comprehension is a dynamic and active process that allows the reader to build coherent mental representations and to make inferences from the text within the limits of the amount of information that can be maintained in working memory (Graesser & Britton, 1996). In primary school, children should learn how to integrate content across the text, draw inferences, monitor their comprehension, activate their background knowledge, and identify the text structure (Cain, 2009). Furthermore, the seminal model for text comprehension proposed by van Dijk and Kintsch (Kintsch, 1994, 1998; van Dijk and Kintsch, 1983) suggests that the reader must construct a coherent mental representation of the text's meaning at a local and at a global level as well as unify the text content with previous knowledge. All these skills are fundamental to the development of text comprehension since early ages.

Text writing is a complex and multi-component skill that represents the goal of a writer's thinking (Hayes, 2012). The Simple View of Writing model (Berninger et al., 2002) suggests that the three main phases of writing (i.e. planning, reviewing, and revision) are supported by both low-level skills, such as spelling and handwriting fluency, and high-order skills, specifically executive and self-regulatory functions. Since primary school, when children are required to write simple texts, writing narratives requires connecting words in a sentence, linking concepts to the entire text, and organizing the different parts of the production within a coherent structure (Pinto et al., 2015).

1.2. Paper vs digital modes in text comprehension and text writing

According to recent meta-analyses (Clinton, 2019; Delgado et al., 2018; Kong et al., 2018), comprehending a digital text is more difficult than comprehending a paper one. A possible explanation for the negative effect on screen reading is based on the "*shallowing hypothesis*" (Annisette & Lafreniere, 2017). It suggests that the frequent use of social media, characterized by rapid exchanges, immediate rewards, superficial interactions, and a tendency to multitasking, has led to a decline in reflective thinking and sustained attention in complex tasks such as reading comprehension. Another possible interpretation of the digital reading disadvantage could be the higher cognitive and metacognitive involvement required by digital medium in comparison to paper one, due to the unfamiliarity with digital tools (Ackerman & Lauterman, 2012; Sanchez & Wiley, 2009). However, these hypotheses have been formulated by studies on undergraduates and thus, they cannot be straightforwardly applied to early phases of reading acquisition. Among the studies comparing digital and paper text comprehension at school age, the results found are contradictory: some support an advantage of paper (Golan et al., 2018; Halamish & Elbaz, 2020; Lenhard et al., 2017; Støle et al., 2020) while others found no difference between the two modes (Aydemir et al., 2013; Florit et al., 2022; Higgins et al., 2005).

For what concerns writing, in literature there is a heated debate on the comparison between paper and digital writing according to writing measures analysed and population involved. Some authors believe that paper writing must be favored during the acquisition of writing skills because it supports cognitive development (e.g., Dinehart, 2015). On the other hand, other authors underline the usefulness of technological devices to learn writing in early phases and to motivate students (Genlott & Grönlund, 2013; Trageton, 2012), especially those with specific learning disabilities (e.g. Berninger et al., 2015). A recent meta-analytic review (Feng et al., 2019), comparing paper and digital writing, showed that text quality is similar in these two writing modes, writing fluidity is correlated across the paper and digital mode, and the digital mode allows for faster writing. Another review (Wollscheid et al., 2016) suggested considering the participants' age when comparing outcomes of paper and digital writing as young writers could write longer texts by pen than by keyboard (Berninger et al., 2009).

It can be hypothesised that part of the discordance in the literature results can be due to the presence of a high inter-individual variability both in reading and writing and in the underlying cognitive control processes. Such variability could be particularly expected in school-age as reading, writing and EF show the highest developmental changes.

1.3. The role of executive functions in text comprehension and text writing

Executive Functions (EF) are a set of top-down mental processes, higher-level functions that are consciously controlled by the subject and implemented strategically. These mental processes are essential for an individual's physical and psychological health and for their cognitive, social, and psychological development (Diamond, 2013). The construct of EF was initially considered by some authors as a unitary domain (Baddeley, 1992; Norman & Shallice, 1986), but more recent theories tend to interpret this construct as consisting of several components (Diamond, 2013; Miyake et al., 2000). Specifically, three basic EF components can be differentiated, even if they are strictly interrelated, based on EF fractionated models (Diamond, 2013; Miyake et al., 2000): inhibitory control, working memory/updating and cognitive flexibility/switching. According to the developmental perspective (Lee et al., 2013), the first component to develop is inhibitory control. Inhibitory control includes two components: Response Inhibition (RI), the ability to inhibit automatic responses in favor of new and context-appropriate responses, and Interference Control (IC), the ability to suppress interfering stimuli while maintaining attentional focus on a predefined target stimulus. The second EF to emerge is the Working Memory (WM), a mental process that allows to check, update, work and monitor mental information and update the representation held in short-term memory. In Miyake's model (2000), the second EF component is named updating, which is a specific process of WM, referring to the capacity to update temporary information held in memory. Cognitive Flexibility (CF), also referred as switching, the last EF to develop, is based on the ability to shift mental strategies, rules and activities avoiding perseveration or automatisms. These three EF components are the basis of more complex EF, such as abstract reasoning, problem solving, and planning (Diamond, 2013).

EF have been extensively studied in the literature in relation to school learnings and have been included as supportive factors in recent cognitive models of reading comprehension (DRIVE model, Cartwright & Duke, 2019) and writing (DIEW model, Kim & Schatschneider, 2017). In detail, although most of the literature investigated the role of WM, a recent meta-analysis on 29 studies shows the involvement of all EF basic components in text comprehension (Follmer, 2018). This paper found that during reading comprehension students must: (a) inhibit irrelevant mental and textual information by focusing only on the one relevant for the task; (b) maintain, integrate, and update the incoming information and ideas in working memory as well as (c) use flexibly different reading strategies (Carretti et al., 2017; Garcia-Madruga et al., 2013). The role of EF in text comprehension skills is further supported by studies in children with low levels of text comprehension. Carretti et al. (2005) found that poor comprehenders scored lower performances in a WM updating task than good comprehenders. Poor comprehenders made more intrusion errors than good comprehenders. The results were interpreted as suggesting that the ability to control for irrelevant information maintained in WM mediates the relation between reading comprehension and WM. Similar results were subsequently found in other more recent studies (e.g., Borella et al., 2010; Linares & Pelegrina, 2023; Pelegrina et al., 2015) supporting the hypothesis that reading comprehension difficulties are associated with low levels of executive processes.

Moreover, to date, studies demonstrating the relationship between text comprehension and EF have mainly used paper and pencil materials, lacking to study the relation between EF and comprehension of digital texts. Only few recent studies investigated digital text comprehension in relation to WM, demonstrating an involvement of this EF component in adolescents and young adults, especially in resource-demanding conditions (Burin et al., 2021; Hahnel et al., 2017); however, this finding was not confirmed in young children (Fesel et al., 2018).

Many authors investigated the EF involvement in the writing process (e.g. Berninger & Winn, 2006; Drijbooms et al., 2015; Kellogg et al., 2013,2022). Inhibition can help in selecting the ideas the writer wants to write (textual level) and the words and grammatical structures needed, while also inhibiting wrong lexical representations (sentence level). Updating is a fundamental process in WM for drafting a text as it allows to continually update in memory the contents progressively written and to retrieve from long-term memory new contents to work on and to be adapted in the text. Finally, cognitive flexibility is associated with the generation of creative ideas (textual level) and the ability to move between mental sets of lexical representations. A recent systematic review (Ruffini et al., 2023) on the relationship between EF and writing in children confirms the involvement of all EF basic components in writing. In addition, a number of studies included in the systematic review investigated the relationship between the two constructs in poor and good writers, showing that performance levels in WM (Costa et al., 2018), inhibition and cognitive flexibility (Hooper et al., 2011) tasks were significantly different between the two groups. Most of the studies compared paper and digital writing in terms of writing outcomes, not assessing the different cognitive processes involved. The lack of spatial delimitations, the need to coordinate visuo-motor aspects, the several icons within the screen during digital writing could implicate a higher involvement of EF components in comparison to paper writing.

In summary, few studies compared the effect of mode (digital versus paper) on text comprehension and writing in the early stages of acquisition, with discordant results. Part of the discordance could be explained by a higher variability in the primary school period, in performance on reading and writing tasks and executive functioning compared to adulthood.

1.4. Aim of the study

Given the mentioned literature, it is important to provide further studies comparing paper and digital modalities in reading and writing and investigating the role played by the different performance levels and executive functioning in primary school.

Three main research aims (RA) guided this inquiry:

RA1) to investigate the differences in performances between paper and digital modalities in text reading and text writing in primary grade students;

RA2) to analyse whether EF predict performances in paper and digital modalities;

RA3) to explore whether any differences between paper and digital text comprehension or writing can be differently explained by EF depending on the children's learning performances.

With reference to RA1, it was assumed that given the low expertise of the young population in both digital and paper modes, no differences between the two modalities were expected at the group level on text comprehension or text writing skills. For RA2, considering the role of EF in supporting text comprehension and writing in the paper mode, an involvement of EF was also expected in the digital mode with different roles for the various EF components. Considering RA3, it was assumed that EF would explain differences between digital and paper to a different degree depending on the children's performances in the reading and writing tasks. Given that lower performances are expected from younger children, the school grade was taken into account.

2. Methods

2.1. Participants

This study was approved by the ethics commission of the University of Florence and conducted in 9 different primary schools in a central region of Italy, Tuscany, during the academic year 2021/2022. This project was presented to several primary schools in Tuscany through an interview with the school directors to explain aims and procedures. The schools were part of the university network. Grades 3–5 students were invited to participate to the project as from Grade 3 onwards, text comprehension and free-writing skills are, although still developing, more automated. Participating schools were offered a workshop discussing the main results of the study at the end of the project. Following the school directors' written consent, we collected the informed consent from the parents of all participating children. Verbal informed consent was given by all children before each evaluation.

10 primary classes participated in this project for a total sample of 204 children. The mean age of the sample was 9.73 (SD = 0.89, age range: 7.87–12.07) and the children were divided by grade as follows: 38 Grade 3, 80 fourth Grade 4, 86 Grade 5 students. Of the participating children, 95 were females and 35 were bilingual. All children participated in each study session. 29 children presented a neurodevelopmental disorder or impaired performances at the general cognitive test (Coloured Progressive Matrices, Belacchi et al., 2008), and they were excluded from the analysis. The final sample included 175 children with a mean age of 9.75 (SD = 0.89, age range: 7.87–12.07) divided according to grade as follows: 30 Grade 3, 70 Grade 4, 75 Grade 5 students. Of these, 82 children were females. All students spoke Italian and 30 of them were bilingual speaking Italian and at least another language (the second most spoken languages were Albanian, Arabic, Romanian, other less frequent languages were Russian, Portuguese, Japanese, French, English, Moldavian, Filipino, Serbian, Polish, Spanish, Slovak, German). A questionnaire was given to the parents to identify the Socio-Economic Level (SES) of the children's families. The SES was calculated taking into account both the employment status of the parents (working vs. unemployed) and the level of schooling (primary school leaving certificate, middle school leaving certificate, diploma, degree). Thus, SES ranged from a minimum of 2 (unemployed parents with primary school leaving certificate) to a maximum of 10 (working and graduated parents). The SES of the sample group was middle-high (M = 7.72, SD = 1.62, range: 3–10).

2.2. Procedure

The assessment took part in three sessions of about 60 min each one week apart from each other.

In the first session, all children were individually assessed with a test of nonverbal intelligence (Coloured Progressive Matrices, Belacchi et al., 2008) presented in a digital format and three digital tasks of EF.

In the second and third sessions, children completed a text production, and a text comprehension tasks both in the digital or in the paper mode working individually within a class with their classmates. A within-subjects design was used and the order of presentation of the two modes was counterbalanced across the two sessions (digital-paper vs paper-digital). In detail, each class involved in the project was split in half. Half of the class in the second session digitally conducted the text production task followed by the text comprehension task and in the third session repeated the two tasks in paper mode. The other half of the class conducted the two tasks first on paper and then in digital mode. There were two text comprehension texts, and they were balanced between paper and digital mode: of the class subgroup, half performed text A and the other half text B in one mode and then texts were reversed in the other mode. Regarding the text production task, children were asked to not tell the same story in the two modes. Thus, among 175 children, 85 children participated in the paperdigital sessions (order 1) whereas 90 children were assigned to digital-paper session (order 2). In each order, approximately half of the students performed text A in digital mode and text B in paper mode; the other half performed text B in digital mode and text A in paper mode (see Table 1).

A specific setting for digital cognitive and EF assessment within the school was prepared and organised by an in-person operator. A quiet and bright room, possibly without distracting stimuli was chosen. The in-person operator arranged at least one computer with a minimum size of 11 inches on a desk, free of other objects, and positioned at an appropriate height for the child. The child sat 30–50 cm from the PC screen. Digital cognitive and EF assessments were carried out remotely through Skype™, except for two classes that were assessed in presence. Children did not have any previous interaction with the researchers who administered the cognitive test and the EF tasks. For this reason, before starting with the administration of the tasks, children familiarized with the digital device and the room as well as with the researcher (Ruffini et al., 2022).

The reading and writing assessments were conducted by an in-person operator. For digital assessment, a classroom with laptops positioned above the desks was set up. The settings of the digital and paper assessments were similar as in both digital and paper modes children individually completed the reading and writing tasks in a class setting of about 10 pupils. The learning assessments were administered in a unique moment by the in-person operator and the class teacher. The classic school rules that are respected during a class test were implemented.

2.3. Measures

Cognitive and EF tasks, reading and writing digital and paper tasks were collected. Nonverbal intelligence was evaluated by the Colored Progressive Matrices (CPM, Belacchi et al., 2008). The CPM test was used to ensure that the study sample consisted of typically developing children. The test requires to complete a matrix of geometric items according to a logic criterion by choosing among 6 alternatives. The scores of each child were compared with Italian normative reference data and a cut-off of 2 SD under the mean was used (Belacchi et al., 2008).

2.3.1. Executive functions digital assessment

For the assessment of Executive Functions, three standardised digital EF tasks were used following the Latin square design as order of administration. For a detailed description of the three tasks see Appendix 1. All EF measures used in the present study have been previously standardised and reliability indices provided (Rivella et al., 2023).

Response inhibition. To measure response inhibition, the child's ability to block impulsive behaviours in favor of correct responses, the Go/No-Go task was used (adapted from Donders, 1969). The child is asked to press the spacebar as fast as possible when a target stimulus (Go stimulus) is presented on the screen and not to press it when a non-target stimulus (NoGo stimulus) appears. The task was composed of 4 blocks of 50 stimuli each of which 70% Go items (n = 35) and 30% No-Go items (n = 15). The following indexes were computed:

- Go CR = mean of the correct responses to the Go stimuli in the 4 blocks;
- Go RT = mean of the reaction times to the Go stimuli in the 4 blocks;
- No-Go CR = mean of the correct responses to the No-Go stimuli in the 4 blocks.

Go CR and RT are used to assess the adherence to the task. No-Go CR is considered a measure of response inhibition.

Interference control and switching. The Flanker task (adapted from Eriksen & Eriksen, 1974; Diamond et al., 2007) was used to measure the interference control, the ability of the subject to not to be distracted by irrelevant information, and the process of switching interference control rule, the ability to use simultaneously two rules of interference control. The child was required to choose the right direction of the arrows presented in the screen by pressing a key on the PC keyboard: L for right and S for left. The 5 arrows can point all to the right or all to the left (congruent condition), or the arrow in the centre can point in the opposite direction to those on the side (incongruent condition). The task was composed of three blocks: block 1 (Single rule: the child is asked to indicate the direction of the arrow in the centre), block 2 (Single rule: the child is asked to indicate the direction of the four arrows that are beside that one in the centre of the string) measuring interference control and block 3 includes shifting between two rules of interference control (Mixed rules).

Number of correct responses and response time were recorded for each block both for the congruent and incongruent conditions. The indexes in the congruent conditions were used to assess adherence to the task. The indexes in the incongruent conditions were considered measures of interference control and switching between interference control rules.

Updating in working memory. The N-back task was used (adapted from Kirchner, 1958) to measure updating in working memory and it is composed of 6 blocks. The child was asked to respond by pressing the spacebar if the stimulus presented in the screen matched (in terms of colour, shape or letter) the previous stimulus (1-back) or the one earlier (2-back). The index of N-back CR, as the percentage of the number of correct responses in the 6 blocks, was calculated.

Two children could not complete any of the EF tasks because they were absent at the time of the evaluation. 7 children did not respond to at least one of the EF tasks: 1 Go/No-Go, 4 Flanker, 2 N-back.

2.3.2. Reading and writing assessment

Text comprehension (TC). An Italian standardised task to measure Text Comprehension (TC) was used (Cornoldi & Carretti, 2017; Cornoldi & Colpo, 2009). The participants were instructed to read a text and choose the correct answer among four alternative answers without any time limits in both digital and paper modes. The measures used offer age-standardised text options; thus, the two parallel texts were changed according to school grade for research purposes. Text A consists of 10 multiple choice questions while text B consists of 12 multiple choice questions (see Table 2 for detailed description of the texts). Half of the questions were textual, asking for specific details (shallow level of comprehension) while the other half were inferential, requiring inferences based on parts of the texts, across parts of it, and involving also previous knowledge (high-level comprehension).

Table 1
Number of students enrolled in each order according to grade level.

	Paper – digital session	Digital – paper session
Grade 3	14	16
Grade 4	38	32
Grade 5	33	42

The order of the two texts was counterbalanced across two presentation modes: paper (pTC) and digital (dTC). Consistently, the following two conditions were used: digital-paper; paper-digital.

In the digital mode, the child read the passage and answered on the computer screen. The percentage of correct answers per text was calculated. Texts used show good reliability according to standardization data (Cornoldi & Carretti, 2017; Cornoldi & Colpo, 2009).

Text writing (TW). The participants were asked to write a story on a paper or on the computer, without any time limits, any indications about the topic to be addressed or length of the story. To assess both digital (dTW) and paper Text Writing (pTW), the following measures were considered: i) the level of narrative complexity was analysed by identifying eight constituent elements (Pinto et al., 2008): title, conventionality of the opening, characters, setting, problem, development of the story, solution of the problem, conventionality of the conclusion, whose presence or absence determined the attribution of one of the five levels. A score from 1 (lowest level) to 5 (highest level) was assigned (Appendix 2); ii) number of words: number of words used in the entire written composition, including articles, prepositions, function words, etc; iii) % of orthographic errors (e.g., grapheme and words substitutions, omissions, inversion) on the total number of words. The writing task used show good reliability in previous studies (Pinto et al., 2008, 2015). In the present study, two independent judges coded 72 written productions with an interrater agreement of 81%.

2.4. Statistical analysis

Statistical analyses were conducted through SPSS 2022, version 28.0.1.0 (142).

Descriptive exploratory statistics were carried out on all measures. Analysis of the normality of the distribution (skewness cut-off = 2; kurtosis cut-off = 3) and outlier removal were conducted on each dependent variable. The following inferential analyses were planned:

1. To verify the hypothesis of absence of differences between paper and digital modes at the whole-group level (RA1), paired *t*-tests were run on Text Comprehension (TC) and Text Writing (TW) performances. Paper (p) versus digital (d) mode was the independent variable, whereas Text Comprehension and Text Writing performances were the dependent variables.
2. Multivariate linear regression analyses were conducted to investigate the role of EF in explaining the variance of Text Comprehension and Text Writing performances (RA2). EF components were included as predictors and Text Comprehension and Text Writing performances as dependent variables.
3. To explore whether differences between paper and digital text comprehension or writing can be differently explained by EF depending on the children's learning performances (RA3), children were categorised as "Low Performers" when the scores obtained in the paper tasks (comprehension and writing separately) were below the median and "High Performers" when they were equal to or above the median. Mixed ANOVAs, with group (Low Comprehenders vs High Comprehenders; Low Writers vs High Writers) and grade (3, 4, 5) as between factors and mode (paper vs digital) as within factor, were used to verify whether any differences between paper and digital text comprehension or writing depended on learning performances (being a Low or a High performer). To better understand the moderating role played by grade, we performed a series of Mixed ANOVAs separately for each grade, with group (Low Comprehenders vs High Comprehenders; Low Writers vs High Writers) as between factor and mode (paper vs digital) as within factor. To investigate if Low and High performers differed on EF measures, MANOVAs were used, with group (Low versus High performers) as the independent variable and EF performances as the dependent variable.

Lastly, linear regressions separately for each group (Low Comprehenders, High Comprehenders, Low Writers, High Writers) were conducted to check if differences between paper and digital text comprehension or writing could be differently explained by EF in Low and High performers. EF were included as predictors and paper-digital differences in each comprehension/writing task were included as dependent variables.

For each comparison, Cohen's d and partial eta squared (η_p^2) were considered to express the effect size.

3. Results

An explorative analysis was used to identify and eliminate the outliers of the distribution of the dependent variables used for inferential analyses. The number of outliers ranged from 1 to 4 across dependent variables. After outlier removal, all variables were normally distributed. Descriptive statistics of the performances at the TC, TW and EF tasks are reported in Appendix 3.

Table 2
Detailed description of the parallel texts used.

	Text A	Text B
Grade 3	words: 179	words: 220
	Gulpease readability index: 60	Gulpease readability index: 83
Grade 4	words: 268	words: 252
	Gulpease readability index: 62	Gulpease readability index: 63
Grade 5	Beginning version words: 225; end version words: 200	words: 313
	Gulpease readability index: beginning version: 57; end version: 60	Gulpease readability index: 54

3.1. Text comprehension

Paired *t*-test on the percentage of correct responses (CR) in the TC tasks showed the absence of differences between digital and paper modes with small effect size ($t(174) = -0.43$, $p = .671$, $d = 0.04$) and delta values (differences in % of CR) ranging from −82 to 58.

Linear regression analysis showed that EF measures (No-Go CR, Single rule incongruent CR; Single rule incongruent RT; Mixed rules incongruent CR; Mixed rules incongruent RT, N-back CR) significantly predicted the percentage of correct responses at the TC task in both paper ($F(6, 162) = 2.66$, $p = .018$) and digital ($F(6,162) = 2.6$, $p = .02$) modes, explaining 9.3% and 9.1% of variability, respectively. Only the coefficient of the N-back CR in the TCd was significant ($\beta = 0.24$, $p = .007$).

To explore whether any differences between paper and digital text comprehension can be differently explained by EF depending on the children's learning performances, children were categorised as Low Comprehenders (LC, scores under median) or High Comprehenders (HC, scores equal to or above median) at the pTC task. Results from a mixed ANOVA (group and grade as between factors and mode as within factor) showed a significant interaction between group, mode and grade ($F(2,169) = 6.37$, $p = .002$, $\eta_p^2 = 0.07$), a significant interaction between group and mode ($F(1,169) = 64.62$, $p < .001$, $\eta_p^2 = 0.28$), no interaction between mode and grade ($F(2,169) = 2.46$, $p = .09$, $\eta_p^2 = 0.03$), no effect of mode ($F(1,169) = 0.89$, $p = .35$, $\eta_p^2 = 0.01$) and a significant main effect of the group ($F(1,169) = 93.07$, $p < .001$, $\eta_p^2 = 0.36$). Visual inspection of the descriptive statistics suggests that the interactions were due to better performances of Low Comprehenders in the digital than paper mode and the reverse pattern in the High Comprehenders, although differences between modes tended to decrease with grade (a graphic representation is reported in Appendix 4).

The results of the mixed ANOVAs conducted in each grade are reported in Table 3. A significant interaction between mode and group was found in each grade: LC performed better in the digital mode whereas HC showed the advantage of paper mode.

Visual inspection of descriptive statistics of the EF measures showed worse performances of the LC group in comparison to the HC group in all measures, but MANOVA revealed significant differences between LC and HC, with large effect sizes, only in the Flanker task (mixed rules incongruent condition CR), and CR of the N-back task (see Table 4).

Two linear regression analyses showed that the EF components, which significantly differed between the two groups, predicted the digital-paper difference in the LC group ($F(2,68) = 3.26$, $p = .045$, $R^2 = 0.09$), with CR of the N-back task as significant predictor ($\beta = 0.30$, $p = .016$), but not in the HC group ($F(2,94) = 3.03$, $p = .053$, $R^2 = 0.06$).

3.2. Writing

Paired *t*-tests showed that between digital and paper modes there were significant differences in the number of words ($t(168) = 3.2$, $p = .002$, $d = 0.24$) with low-moderate effect sizes. In the paper mode, children wrote less words than in the digital mode. No differences between digital and paper modes emerged in the level of narrative complexity ($t(173) = 1.75$, $p = .083$) and in the % of errors ($t(171) = 0.56$, $p = .575$).

Linear regression models with EF measures as independent variables and writing measures (level of narrative complexity, number of words, % of errors) as dependent variables showed that N-back CR was a significant and unique predictor of the level of narrative complexity (paper: $F(6,162) = 2.71$, $p = .016$, $R^2 = 0.09$, $\beta = 0.26$, $p = .003$; digital: $F(6,161) = 2.93$, $p = .01$, $R^2 = 0.10$, $\beta = 0.2$, $p = .024$), paper number of words ($F(6,158) = 5.32$, $p < .001$, $R^2 = 0.17$, $\beta = 0.27$, $p = .002$) and digital % of orthographic errors ($F(6,160) = 4.02$, $p < .001$, $R^2 = 0.14$, $\beta = -0.22$, $p = .011$). N-back CR ($\beta = 0.29$, $p < .001$) and mixed rules incongruent CR ($\beta = 0.2$, $p = .036$) were significant predictors of digital number of words ($F(6,160) = 6.95$, $p < .001$, $R^2 = 0.21$). Paper % of orthographic errors were explained by EF ($F(6,161) = 2.34$, $p = .033$, $R^2 = .08$) with no significant predictors.

In order to verify whether performance level in the TC task and the EF skills affected the differences between paper and digital writing measures, children were categorised, according to the level of narrative complexity median scores in the pTW task, in Low Writers (LW) for scores under the median, and High Writers (HW) for scores equal to or above median. Results from mixed ANOVAs with group and grade as between factors and paper vs digital mode as within factor are reported below for each writing measure and graphically represented in Appendix 5.

Referring to the level of narrative complexity, results from the mixed ANOVA showed significant interactions between group, mode and grade ($F(2,168) = 10.09$, $p < .001$, $\eta_p^2 = 0.11$), between group and mode ($F(1,168) = 34.97$, $p < .001$, $\eta_p^2 = 0.17$), between mode

Table 3
Results of Mixed ANOVAs, with group (LC vs HC) as between factor and mode (paper vs digital) as within factor conducted for each grade.

					Group * mode			Mode effect			Group effect		
Grade		n	paper M (SD)	digital M (SD)	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
3	LC	18	46.22 (11.39)	65.06 (25.69)	37.47	**<.001**	.57	4.04	.054	.13	2.72	.11	.09
	HC	12	81.67 (8.35)	44.42 (14.77)									
4	LC	28	45.57 (10.51)	58.11 (19.56)	12.69	**<.001**	.16	.21	.65	.00	120.18	**<.001**	.64
	HC	42	85.74 (10.49)	76.07 (22.32)									
5	LC	30	52.30 (8.17)	64.17 (20.67)	13.56	**<.001**	.16	.58	.45	.01	47.48	**<.001**	.39
	HC	45	80.78 (12.40)	72.98 (19.59)									

Legend: HC (High Comprehenders); LC (Low Comprehenders).

Table 4
Mean (and standard deviations) of performances at the EF tasks by the LC and HC groups.

			n	M (SD)	F	p	η_p^2
Go/No-Go task	No-Go CR	LC	74	11.28 (2.14)	.10	.76	.00
		HC	97	11.57 (1.95)			
Flanker task	Single rule incongruent CR	LC	74	14.71 (4.45)	2.96	.09	.02
		HC	95	16.19 (4.23)			
	Single rule incongruent RT	LC	74	905.43 (172.28)	2.3	.13	.01
		HC	95	861.12 (167.86)			
	Mixed rules incongruent CR	LC	74	17.82 (5.86)	10.89	**.001**	.06
		HC	95	20.98 (5.54)			
	Mixed rules incongruent RT	LC	74	1254.76 (183)	.76	.38	.01
		HC	95	1242.89 (173.41)			
N-back task	N-back CR	LC	69	84.89 (4.77)	8.91	**.003**	.05
		HC	97	87.33 (5.04)			

Legend: CR (Correct Responses); HC (High Comprehenders); LC (Low Comprehenders); RT (Reaction Time).

and grade ($F(2,168) = 6.14$, $p = .003$, $\eta_p^2 = 0.07$), no effect of mode ($F(1,168) = 1.01$, $p = .32$, $\eta_p^2 = 0.01$) and a significant main effect of the group ($F(1,168) = 291.58$, $p < .001$, $\eta_p^2 = 0.63$). These interactions suggest that, regardless of the grade, High Writers had a higher performance in the paper mode than in the digital mode, whereas the opposite trend was found for Low Writers, who scored higher in the digital mode. The results of the mixed ANOVAs conducted in each grade are reported in Table 5. A significant interaction between mode and group were found in each grade. Grades 3 and 5 Low Writers performed better in the digital mode than in the paper one, an opposite trend compared to High Writers (see Table 5). Grade 4 students, regardless of their performance levels, performed better in the paper mode than the digital one.

Referring to the number of words, results from the mixed ANOVA showed significant interactions between group, mode and grade ($F(2,163) = 4.12$, $p = .018$, $\eta_p^2 = 0.05$), between mode and grade ($F(2,163) = 10.41$, $p < .001$, $\eta_p^2 = 0.11$), no interaction between group and mode ($F(1,163) = 0.55$ $p = .46$, $\eta_p^2 = 0.00$), an effect of mode ($F(1,163) = 7.7$, $p = .01$, $\eta_p^2 = 0.05$), and a significant main effect of group ($F(1,163) = 18.53$, $p < .001$, $\eta_p^2 = 0.10$). According to visual inspection of descriptive statistics, the interactions were due to higher differences between paper and digital modes in both groups (High Writers and Low Writers) in Grade 5 in comparison to Grades 3 and 4. The results of the mixed ANOVAs conducted in each grade are reported in Table 5. Grades 3 and 4 Low Writers and High Writers did not show significant differences between digital and paper number of words (Table 5). Both Grade 5 Low and High Writers wrote a higher number of words in the digital in comparison to the paper mode.

Referring to the % of orthographic errors, results from the mixed ANOVA showed no interactions between group, mode and grade ($F(2,166) = 1.55$, $p = .22$, $\eta_p^2 = 0.02$), between group and mode ($F(1,166) = 0.00$, $p = .95$, $\eta_p^2 = 0.00$), between mode and grade (F

Table 5
Results of Mixed ANOVAs, with group (LW vs HW) as between factor and mode (paper vs digital) as within factor conducted for each grade.

						Group * mode			Mode effect			Group effect		
Grades			n	paper M (SD)	digital M (SD)	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
Level of narrative complexity	3	LW	22	1.45 (.74)	1.55 (.91)	7.41	**.011**	.21	4.88	**.04**	.15	103.32	**<.001**	.79
		HW	8	4.88 (.35)	4.00 (1.07)									
	4	LW	27	2.07 (.73)	2.04 (1.02)	4.03	**.049**	.06	5.17	**.026**	.07	140.9	**<.001**	.68
		HW	42	4.31 (.47)	3.71 (1.13)									
	5	LW	25	1.68 (.63)	3.28 (1.28)	47.19	**<.001**	.39	4.27	**.042**	.06	74.01	**<.001**	.50
		HW	50	4.42 (.5)	3.56 (1.37)									
Number of words	3	LW	22	81.82 (41.36)	56.18 (37.37)	2.23	.15	.07	.31	.58	.01	30.99	**<.001**	.53
		HW	8	136.25 (15.78)	148.00 (76.78)									
	4	LW	27	105.56 (55.46)	113.52 (57.13)	.09	.77	.00	.56	.46	.01	16.78	**<.001**	.20
		HW	41	165.68 (68.93)	169.07 (70.43)									
	5	LW	25	162.56 (74.82)	259.68 (129.53)	6.3	**.01**	.08	23.42	**<.001**	.25	2.76	.10	.04
		HW	46	235.07 (97.63)	265.85 (122.67)									
% of errors	3	LW	20	8.91 (5.68)	10.46 (7.33)	1.1	.31	.04	.04	.84	.00	4.82	**.04**	.16
		HW	8	5.44 (5.01)	4.40 (2.46)									
	4	LW	27	6.71 (5.92)	5.60 (5.93)	.85	.36	.01	.43	.51	.01	.89	.35	.01
		HW	42	5.03 (4.83)	5.21 (4.82)									
	5	LW	25	4.63 (4.83)	3.39 (3.82)	2.23	.14	.03	3.05	.09	.04	.82	.37	.01
		HW	50	3.31 (2.99)	3.22 (3.63)									

Legend: HW (High Writers); LW (Low Writers).

(2,166) = 0.32, p = .73, $\eta_p^2 = 0.00$), no effect of mode (F(1,166) = 0.45, p = .50, $\eta_p^2 = 0.00$) and a significant main effect of group (F (1,166) = 8.42, *p* = .004, $\eta_p^2 = 0.05$). The results of the mixed ANOVAs conducted in each grade are reported in Table 5. Grades 3–5 LW and HW showed no significant differences between digital and paper % of orthographic errors.

Comparison between LW and HW in the performances at the EF task showed (see Table 6) worse performances of the LW group in comparison to the HW group in all measures with significant differences in mixed rules incongruent CR and N-back CR and medium-large effect sizes.

Three linear regression analyses were conducted for each group (LW and HW), including as predictors the EF components which significantly differ between the two groups and as outcome variable the digital-paper difference in the writing measures. The linear regression analyses conducted on LW group, showed that EF predicted the digital-paper difference in the level of narrative complexity (F(2,66) = 3.23, *p* = .046, $R^2 = 0.09$) and in the number of words (F(2,66) = 7.02, *p* = .002, $R^2 = 0.18$), with mixed rules incongruent CR as significant predictor (β = 0.30, *p* = .024; β = 0.33, *p* = .008). The linear regression analyses conducted on the LW group with % of orthographic errors as outcome variable was not significant (F(2,63) = 1.04, p = .36, $R^2 = 0.03$). The linear regression analyses conducted on HW group, with the level of narrative complexity (F(2,95) = 1.19, p = .31, $R^2 = 0.03$), the number of words (F(2,91) = 0.10, p = .9, $R^2 = 0.00$) or the % of orthographic errors (F(2,95) = 1.37, p = .26, $R^2 = 0.03$) as outcome variables were not significant.

4. Discussion

The present study aimed to investigate the effect of the mode, paper vs digital, on text comprehension and writing in primary school aged children, with a focus on the role of Executive Function (EF) and of the children's performances. To our knowledge, this is the first study to measure in primary school the benefits/costs of reading and writing a text in the digital mode in comparison to the paper one while also considering the underlying role of basic EF components. This study focused on text comprehension and writing as they are both complex and day life tasks in primary school, highly involving top-down cognitive processes. To avoid confounding variables, the paper and digital modes were reduced to the minimal differences, presenting digital tasks on the computer without using multimedia stimuli. With regards to EF, response inhibition, interference control, updating, and switching were measured as they represent the basic EF components and are known to show important age-dependent changes during childhood (Diamond, 2013; Miyake et al., 2000).

Referring to the text comprehension task, as a first result, it emerged that there were no differences in performances between the digital and paper modes. This result is in discordance with previous literature findings (Clinton, 2019; Delgado et al., 2018; Kong et al., 2018) reporting better performances in paper in comparison to digital text comprehension. However, in the meta-analysis by Delgado et al. (2018), paper-based reading advantage was consistent across studies involving mostly undergraduates and using informational texts or a mix of informational and narrative texts, but not on those using only narrative texts, like the current study did. Moreover, differently from previous research, this study analysed whether paper/digital differences could depend on performance level. Indeed, considering population subgroups, in particular high versus low comprehenders, differences across modes emerged. Low comprehenders obtained higher performances in the digital mode whereas children with good text comprehension skills scored higher in the paper mode. This interaction, although fading with grade, is held in each grade from 3 to 5. Thus, the digital mode may have an advantage in specific population subgroups, such as children with low levels of text comprehension. This result could appear in contradiction with the shallowing hypothesis (Annisette & Lafreniere, 2017), according to which increasing use of digital devices for pleasure and enjoyment leads to a tendency to read superficially digital texts without reaching deep levels of text comprehension. However, this theory was formulated for adult readers, whereas text comprehension tasks could be less demanding in terms of depth of comprehension in childhood. Moreover, primary school grade students probably have not yet linked reading on paper with duty and reading on digital tools with leisure (Florit et al., 2022). These two characteristics could justify the absence of a paper advantage at the overall group level in primary grade students. Notwithstanding, this hypothesis is not testable with the data available in the present study. Thus, further careful investigation to assess the digital habits of the pupils, as well as the level of comprehension and the type of questions (e.g. informational versus inferential), that may be facilitated by the digital mode compared to the paper one, are needed. In addition, it can be hypothesised that the digital mode supports children's motivation (Florit et al., 2022; Golan et al., 2018), with

Table 6

Mean (and standard deviations) of EF performances by the LW and HW groups.

			n	M (SD)	F	p	η_p^2
Go/No-Go task	No-Go CR	LW	73	11.09 (2.03)	2.74	.1	.02
		HW	98	11.72 (2.01)			
Flanker task	Single rule incongruent CR	LW	72	14.86 (4.41)	1.28	.26	.01
		HW	97	16.05 (4.30)			
	Single rule incongruent RT	LW	72	906.42 (172.25)	2.47	.23	.02
		HW	97	861.30 (167.9)			
	Mixed rules incongruent CR	LW	72	18.25 (5.79)	5.29	**.023**	.03
		HW	97	20.6 (5.76)			
	Mixed rules incongruent RT	LW	72	1243.69 (176.22)	.05	.82	.00
		HW	97	1251.35 (178.83)			
N-back task	N-back CR	LW	70	84.74 (6.06)	10.76	**.001**	.06
		HW	96	87.46 (3.82)			

Legend: CR (Correct Responses); HW (High Writers); LW (Low Writers); RT (Reaction Time).

greater effects in those children who have difficulty with comprehension and therefore less motivation for the task. In order to test this hypothesis, future studies could include measures of self-assessment of task motivation. Nevertheless, as an educational implication, the finding of the present study suggests that we should consider the mode through which a text is presented to school-age children, as children with different text comprehension skills could differently perform in the paper or digital mode.

Moreover, according to our results, EF basic components played a significant role in supporting text comprehension, both in the digital and paper mode. The regression model showed that, altogether, EF measures explained about 9% of variance of paper and digital text comprehension and that only updating skills in working memory was a significant predictor of digital text comprehension. This evidence confirmed the results of several studies supporting the role of EF in sustaining paper text comprehension during developmental age (Butterfuss & Kendeou, 2018; Hung, 2021; Spencer et al., 2020) and the fundamental role of working memory (Florit et al., 2020; Nouwens et al., 2021; Raudszus et al., 2018) especially in digital text comprehension (Florit et al., 2022). Interestingly, low comprehenders, compared to high comprehenders, displayed lower performances in most of the EF measures, with large differences in updating in working memory, in line with evidence in literature (Borella et al., 2010; Carretti et al., 2005; Linares & Pelegrina, 2023; Pelegrina et al., 2015). This result together with the finding that working memory explains the paper-digital difference only in low comprehenders suggests that the advantage of digital mode in this group could be in part linked to reduced working memory resources.

Altogether the results found on text comprehension suggest providing digital support and to empower updating in working memory in primary schoolers struggling with text comprehension.

For what concerns text writing, a written composition task was chosen as it is an elaborate and demanding measure of writing, usually required in the last years of primary school (Drijbooms, et al., 2015). The analysis of differences in paper and digital writing performances showed that the texts produced in the paper format were shorter, but not narratively more complex or orthographically more correct, than the digital texts. These results are discordant with those finding a general paper advantage in text complexity (Connelly et al., 2007; Read, 2007), but in agreement with recent evidence of equality between handwriting and keyboarding in young writers (Spilling et al., 2022). In addition, considering Grades 3 and 5 students with low writing skills compared to those with high writing skills, it emerged, in accordance with the finding on text comprehension, that the former ones produced more complex texts in the digital mode, as opposed to the latter ones who obtained higher scores in the paper mode. However, this result should be taken with caution as in our study it was not valid for Grade 4 students, who regardless of their writing performance levels, performed better in the paper mode than the digital one. Our finding seems to suggest that children with low writing skills may benefit from digital mode in building a well-organised and meaningful story, with characters, time and spatial references well defined. Future studies may help in verifying which factors (e.g. child's motivation, speed of writing) can make the digital mode more efficient in low writers. As for the number of words, both low and high writers wrote longer texts on the computer in comparison to paper, a finding which is not confirmed for Grade 3 students with low writing performances. This result can be explained by the typically higher speed of the keyboard compared to handwriting (Feng et al., 2019), extending to older children but not to younger populations who are not yet accustomed to the keyboard (Maxam & Stocker, 1993). For what concerns orthographic accuracy, although not representing the main aim of the present study, a digital advantage was expected as keyboarding is often prescribed to subjects with orthographic difficulties. However, no differences were found between the two modes in either subgroup. It can be suggested that larger differences between paper and digital modes could be found in children with relevant orthographic difficulties trained to keyboarding.

A significant contribution of EF was found for all text writing outcomes too, explaining between 9 and 21% of variance in quality of text produced, number of words and orthographic errors in both modes, paper and digital. Updating in working memory was the significant predictor of all text writing measures in the two modes, except for paper percentage of orthographic errors. It is suggested that updating and working on mental concepts held in memory help writers to write more complex, grammatically correct, and longer texts, in both the paper and digital modes. The results of this study confirm the previous knowledge about paper mode by underlying the role of updating in working memory on digital writing in children (Alamargot et al., 2015; Salas & Silvente, 2020). Noteworthy is the involvement of shifting rules of interference control in the number of words in the digital mode. Although no previous studies exist to suggest an interpretation, it is plausible that this executive component could help the child in choosing the right stimuli, that is letters, in a new writing setting such as the use of a keyboard. It must be noted that, again, low writers obtained worse performances in updating in working memory and shifting of interference control rules in comparison to high writers and that in low writers, but not in high writers, cognitive flexibility explained the digital-paper difference of level of narrative complexity and of number of words. The results suggest that intervening on EF basic components is crucial for children with writing difficulties to reduce the difference between digital and paper performances. In sum, these results imply that the computer is a useful tool that allows children with writing difficulties to produce more complex and qualitatively better texts, perhaps relieving them of the burden of cognitive processes involved in paper writing. Thus, as well as for text comprehension, when a writing task is assigned to children to be conducted on the computer or on paper, it is important to evaluate children's functioning profile, both in terms of performance level and EF.

4.1. Limitations and future directions

It is important to underline some limitations of the study. Firstly, for what concerns the comprehension task, the study did not include complex narrative texts nor differentiated informational from inferential questions, thus neglecting the possibility that the differences between paper and digital modes could interact with the type of text and the levels of demand (Florit et al., 2023). Secondly, no direct comparisons between reading and writing tasks were conducted, whereas it could be interesting to investigate how the effect of the digital versus paper mode and the role of EF basic components could be related between the two tasks. A further limitation of the study is that we did not control for the possibility that between sessions the children would tell each other about the contents of the tasks they had completed. As a fourth limitation, in the writing software used (e.g. Word), the autocorrect function was deactivated, thus children did not use digital cues. Future studies should take into consideration the use of the auto-corrector in writing software. Then, as the recruitment procedure was not completely random but rather based on the interest of the school institutions and teachers to participate in the study, further researchers including larger and more representative samples or controlling for intervening environmental variables could be needed. A further limitation of the study was that the median-split of the sample according to the performances did not exclude the middle values, thus making sub-samples very close to each other. Further studies could focus on the comparison of low and high performers according to more stringent criteria, for instance by comparing children in the first quartile (at/below 25%) with respect to children in the last quartile (at/above 75%) of performance. This approach requires large sample sizes, especially if indirect effects are investigated. Moreover, future research could control children's level of digitalization and use of digital tools for entertainment and learning, as these variables could have affected the results. Further studies on larger samples could also investigate whether EF performance predicts reading and writing performance to a different extent depending on whether students have high or low EF skill. In addition, future research could investigate the difference between digital and paper in comprehension and writing by investigating the role of EF also in atypical populations, thus using more strict criteria to identify children with deficits. It is indeed possible that digital-paper difference, supported by executive processes, is even more pronounced in children with Neurodevelopmental Disorders, a population who uses computers as a tool for school learning and for communicating with the world. Therefore, further investigating this topic in this population is of utmost importance.

5. Conclusions

This study highlights the presence of a digital advantage in reading and writing by children with low performances and executive functioning. Thus, the results have important implications for the use of digital devices as compensatory and study support tools, not only in children with good learning skills but also in those with reading and writing difficulties. The digital mode could help these children to support reading and writing skills, but it is important to take into consideration children's school performances and executive functioning. Finally, evidence on the involvement of EF components both in paper and in digital learnings are provided, suggesting paying attention to children with weak executive functioning and intervening in this population to foster better academic outcomes.

Credit author statement

Costanza Ruffini: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing-Reviewing and Editing. Christian Tarchi: Supervision, Writing – original draft, Writing- Reviewing and Editing. Chiara Pecini: Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing-Reviewing and Editing, Supervision, Project administration.

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Institutional review board statement

The research was approved by the Ethic Committee of the University of Florence reference number 0152940 date May 26, 2021. The research was carried out following Ethical guidelines of the Italian Association of Psychology and of the Declaration of Helsinki.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

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Appendix 1. *Detailed description of the three Executive Functions tasks*

Go/NoGo task

The Go/No-Go task measures response inhibition, the child's ability to block impulsive behaviors in favor of correct responses (Donders, 1969). The child sees a 3 cm colored and geometric figure, a yellow or blue circle or triangle, in the center of a black screen (Figure A1). The task is composed of 4 blocks of 50 stimuli each of which 70% Go items (n = 35) and 30% No-Go items (n = 15). In the first block the Go stimulus is yellow, and the No-Go stimulus is blue; in the second block the Go stimulus is blue, and the No-Go stimulus is yellow; in the third block the Go stimulus is the circle, and the No-Go stimulus is the triangle; in the fourth block the Go stimulus is the triangle, and the No-Go stimulus is the circle. Each stimulus has a presentation time of 500 ms. If the child responds by pressing the spacebar before the time limit, the stimulus disappears, otherwise after 500 ms a black blank (neutral screen) appears for a variable duration; this interstimulus interval can last 500, 750 or 1000 ms: the three durations appear for the same number of times. After the black blank the new stimulus is presented. The following indexes are computed:

- Go CR = mean of the correct responses to the Go stimuli in the 4 blocks;
- Go RT = mean of the reaction times to the Go stimuli in the 4 blocks;
- No-Go CR = mean of the correct responses to the No-Go stimuli in the 4 blocks.

Go CR and RT are used to describe the behavior and adherence to the task. No-Go CR is considered a measure of response inhibition.

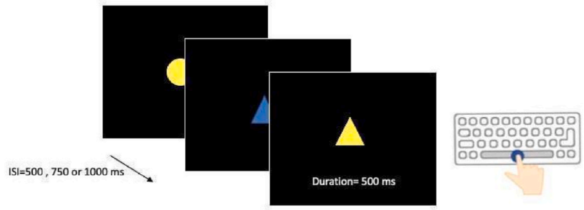

Fig. A1. Exemplification of Go/No-Go task, first block, Go stimuli are yellow.

Flanker Task

The Flanker task measures interference control, the ability of the subject not to be distracted by irrelevant information and the process of switching interference control rule, the ability to simultaneously use two rules of interference control (Eriksen & Eriksen, 1974).

The stimulus is a string of five aligned arrows (long 8.93 mm, distancing 3.84 mm) on a white screen. In 50% of the stimuli, the arrows point all to the right or all to the left (congruent condition), in 50% of the stimuli the arrow in the center points in the opposite direction to those on the side (incongruent condition). The task is composed of three blocks: block 1 and 2 (Single rule) measure interference control and block 3 includes shifting between two rules of interference control (Mixed rules).

In block 1 (Figure A2), arrows are blue, and the child is asked to indicate the direction of the arrow in the center. In block 2, arrows are orange, and the child is asked to indicate the direction of the four arrows that are beside that one in the center of the string.

In block 3, arrows are either blue or orange. If the arrows are blue, the child must indicate the direction of the arrow in the center (as in the first block), while if the arrows are orange, the child must indicate the direction of the side arrows (as in the second block).

In all blocks the child is required to choose the right direction by pressing a key on the PC keyboard L for right and S for left.

Blocks 1–2 include:

– 8 example items, specifically: 2 items in which all the arrows point to the right (congruent condition, right direction), 2 items in which all the arrows point to the left (congruent condition, left direction), 2 items in which the side arrows point to the left and the arrow in the center to the right (incongruent condition, right direction) and 2 items in which the side arrows point to the right and the arrow in the center to the left (incongruent condition, left direction).
– 40 test items (20 congruent conditions of which 10 right and 10 left directions, 20 incongruent conditions of which 10 right and 10 left directions).

The third block includes:

– 64 test items of which 32 blue arrows (16 congruent conditions, 8 right and 8 left directions; 16 incongruent conditions, 8 right and 8 left directions), 32 orange arrows (16 congruent conditions, 8 right and 8 left directions, 16 incongruent conditions, 8 right and 8 left directions).

In all blocks, the child is first shown a screen with a fixation point: a cross that appears in the centre of the screen, where the central arrow will then appear. The central arrow remains for a variable duration of 600–1200 ms. Then the child sees a white screen, lasting

600 ms, followed by the screen with arrows, which has a maximum duration of 1500 ms. The child has a maximum response time of 1500 ms, referable to the duration of the screen with arrows. A response is considered valid if it is given at least within 200 ms after the stimulus is presented as otherwise it could be random.

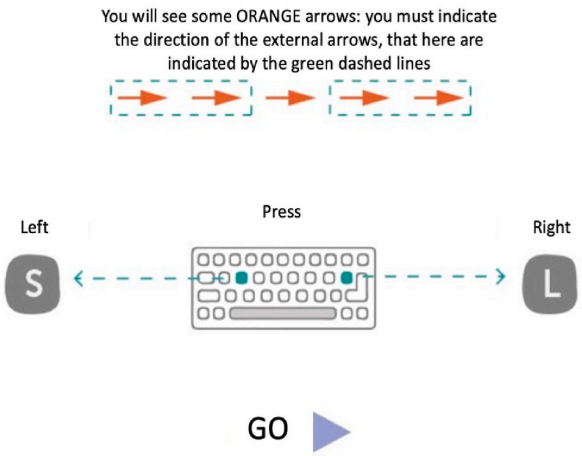

Fig. A2. Flanker Task, block 1, congruent condition

Number of correct responses and response time are recorded for each trial. The following indexes are computed:

- Single rule congruent CR = mean number of correct responses in the congruent conditions of the blocks 1-2
- Single rule congruent RT = mean of the reaction times in the congruent conditions of the blocks 1-2
- Mixed rules congruent CR = number of correct responses in the congruent conditions of the block 3.
- Mixed rules congruent RT = mean of the reaction times in the congruent conditions of the block 3.
- Single rule incongruent CR = mean number of correct responses in the incongruent conditions of the d blocks 1-2
- Single rule incongruent RT = mean of the reaction times in the incongruent conditions of the blocks 1-2
- Mixed rules incongruent CR = number of correct responses in the incongruent conditions of the block 3.
- Mixed rules incongruent RT = mean of the reaction times in the incongruent conditions of the block 3.

The indexes in the congruent conditions are used to describe the behaviour and adherence to the task. The indexes in the incongruent conditions are considered measures of interference control and switching between interference control rules.

N-Back task

The N-back task measures updating in working memory (Kirchner, 1958). The child sees a sequence of stimuli (3 cm), presented one at a time in the middle of a white screen and they must indicate when the current stimulus matches the previous or the n-back one (Figure A3). Six different blocks are proposed in which the stimuli are colours in the first two blocks, shapes in the third and fourth blocks and UPPER-lowercase letters in the last two blocks. The child must respond by pressing the spacebar if the stimulus matches (in terms of colour, shape or letter) the previous stimulus (1-back) or of the one earlier (2-back). Each block has 16 target stimuli and 36 non-target stimuli: block 1 = 1-back colour condition; block 2 = 2-back colour condition; block 3 = 1-back shape condition; block 4 = 2-back shape condition; block 5 = 1-back letter condition; block 6 = 2-back letter condition. Each stimulus has a presentation time of 1500 ms. If the child responds before the time limit, the stimulus disappears, otherwise after 1000 ms a white blank neutral screen appears, which is the interval inter stimuli (ISI).

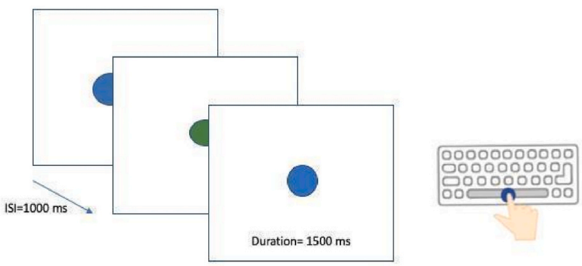

Fig. A3. N-back task, colour block, blue as the target stimulus and green as the non-target stimulus

Responses are considered correct when the subject presses the spacebar at the target stimuli and does not respond to the non-target stimuli. The following index is calculated:

- N-back CR = percentage of number of correct responses in the 6 blocks

Appendix 2. *Level of narrative complexity (Pinto et al., 2008)*

1. No story: no narration, description or listing of facts, objects, aspects of the character; lack of a conclusion and discontinuity in the characters.
2. Sketch of history: various combinations of the eight elements, although the problem and/or the solution and/or the development are absent.
3. Incomplete story: absence of the development, although many of the eight constituent elements are present.
4. Essential story: lack of non-essential elements, such as the setting of the story.
5. Complete story: presence of all the constituent elements; the title may not be present.

Appendix 3

Table. Descriptive statistics of the performances at TC and TW tasks in the paper and digital modes and at EF tasks

Task	Indices	n	M (SD)	Skewness	Kurtosis
TC	% CR paper	175	67.96 (20.34)	−.12	−.83
	% CR digital	175	67.06 (22.41)	−.39	−.68
TW	Level of narrative complexity p	175	3.27 (1.45)	−.38	−1.31
	Level of narrative complexity d	174	3.09 (1.43)	−.21	−1.40
	Number of words p	171	163.46 (92.94)	1.31	1.99
	Number of words d	173	190.20 (125.96)	1.19	1.36
	% errors paper	174	5.37 (5.18)	1.53	2.01
	% errors digital	173	5.03 (5.27)	1.63	2.28
Go/No-Go task	*Go CR*	*172*	*32.40 (4.35)*	*−3.46*	*13.17*
	Go RT	*172*	*449.26 (49.55)*	*.51*	*.28*
	No-Go CR	171	11.45 (2.04)	−.84	.92
Flanker task	*Single rule congruent CR*	*168*	*17.85 (3.51)*	*−2.76*	*8.17*
	Single rule congruent RT	*168*	*777.7 (146.77)*	*.78*	*1.59*
	Mixed rules congruent CR	*168*	*27.24 (5.52)*	*−2.36*	*7.12*
	Mixed rules congruent RT	*168*	*1027.77 (163.65)*	*.30*	*.34*
	Single rule incongruent CR	169	15.54 (4.37)	−1.21	.65
	Single rule incongruent RT	169	880.52 (170.73)	.19	−.44
	Mixed rules incongruent CR	169	19.6 (5.88)	−.11	−.99
	Mixed rules incongruent RT	169	1248.09 (177.24)	−.27	.07
N-back task	N-back CR	166	86.31 (5.06)	−1.12	2.2

In Italic the variables that are not representative of EF and thus not used for the inferential analysis.

Appendix 4

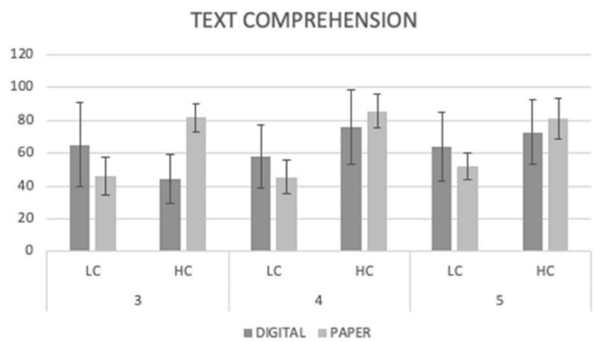

Fig. A4. Representation of performances at digital and paper text comprehension tasks in LC and HC for each grade

Appendix 5

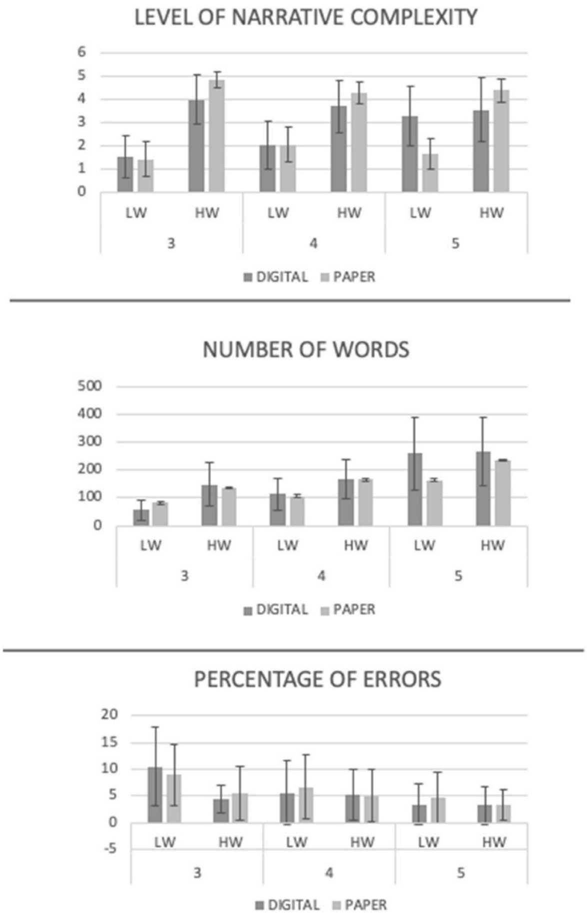

Fig. A5. Representation of performances at digital and paper text writing tasks in LW and HW for each grade

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