

Digital reading in university students: contributions of executive functioning and reading habits

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Received: 23/11/2023

Accepted: 23/04/2024

Abstract

This study examined the comprehension of expository and narrative texts read on screens, and its association with executive functions, reading habits, and reading media of choice (paper or screen) for study or recreational purposes, in university students. Participants were ninety-eight university students (76.8% women, mean age: $M = 20.6$, $DS = 5.24$ years), who completed a screen-based expository and narrative text comprehension task, a computerized executive functions assessment (working memory, cognitive flexibility and inhibition), a survey on reading habits and an author recognition test. Working memory was a general predictor of comprehension, while flexibility was specifically linked to expository text comprehension. Fiction exposure specifically contributed to narrative text comprehension. Students who preferred to study on screens showed better performance on expository text comprehension than those who chose to study on paper. The contribution of executive functions to reading comprehension on screens was similar to that observed in paper-reading studies. The effect of study reading media of choice suggests that practice might compensate the more superficial reading mode that is typically observed in digital media reading studies.

Keywords: Reading comprehension; digital reading; executive function; reading habits; reading motivation; Higher Education.

How to cite: Tabullo, A. J., & Pulifiato-Hamann, E. S. (2024). Digital reading in university students: contributions of executive functioning and reading habits. *Ocnos*, 23(2). https://doi.org/10.18239/ocnos_2024.23.2.424



Lectura digital en estudiantes universitarios: contribuciones del funcionamiento ejecutivo y hábitos lectores

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Recibido: 23/11/2023

Aceptado: 23/04/2024

Resumen

El presente estudio examinó la comprensión de textos expositivos y narrativos en pantalla y su relación con las funciones ejecutiva, los hábitos lectores y el soporte preferido (papel o pantallas) para lectura de estudio o recreativa, en estudiantes universitarios. Participaron noventa y ocho estudiantes universitarios (76.8% mujeres, edad promedio: $M = 20.6$, $DS = 5.24$ años), quienes completaron una tarea de comprensión de un texto expositivo y uno narrativo presentados en pantalla, una evaluación computarizada de las funciones ejecutivas (memoria de trabajo, flexibilidad cognitiva, inhibición), una encuesta de hábitos lectores y un test de reconocimiento de autores. La memoria de trabajo fue un predictor de la comprensión en general, mientras que la flexibilidad se asoció al texto expositivo. La exposición a la ficción contribuyó específicamente al texto narrativo. Los alumnos acostumbrados a estudiar en pantalla tuvieron un mejor desempeño en el texto expositivo que quienes prefieren el papel. La contribución de las funciones ejecutivas a la comprensión en pantallas es similar a la observada en estudios de lectura en papel. El efecto del soporte preferido sugiere que la práctica podría compensar la modalidad de lectura más superficial que se observa típicamente en estudios de lectura en medios digitales.

Palabras clave: Comprensión de textos; lectura digital; funciones ejecutivas; hábitos lectores; motivación lectora; Educación Superior.

Cómo citar: Tabullo, A. J., & Pulifiato-Hamann, E. S. (2024). Lectura digital en estudiantes universitarios: contribuciones del funcionamiento ejecutivo y hábitos lectores. *Ocnos*, 23(2). https://doi.org/10.18239/ocnos_2024.23.2.424



INTRODUCTION

Reading comprehension is a fundamental skill for academic success (Clinton-Lisell et al., 2022), yet a recent meta-analysis indicates that most of Latin American university students only achieve a literal level of comprehension (De-la-Peña & Luque-Rojas, 2021). In Argentina, psychology university students have shown an average performance lower than 70% in a reading comprehension task (Tabullo et al., 2020). On the other hand, the PISA studies point out the tendency of progressive penetration of digital media and displacement of books. This phenomenon was accelerated due to the lockdown restrictions and rise of virtual education modalities during the Covid-19 pandemic (OECD, 2021). Moreover, better performance was observed for reading texts presented on paper, and the preference of this format among adolescents is associated with a higher frequency of recreational reading (OECD, 2021). In this context, it is of interest to analyze the factors that explain the individual differences in reading comprehension presented via digital media among university students.

The model known as Simple View of Reading (Hoover & Tunmer, 2018) suggests that comprehension depends on the coordinated integration of two components: word recognition and language comprehension. These components represent processes linked to the detection and decoding of the orthographic information and the access to the meaning and integration with previous knowledge, respectively. Two abilities were identified as the main predictors to success for comprehension: vocabulary and reading fluency (for a review, see Duke & Cartwright, 2021). In turn, the multicomponential approach (Abusamra et al., 2009) proposes that comprehension depends on a series of subcomponents, whose coordinated interaction allows for prioritizing relevant information and constructing a mental model of its meaning: text content (basic text schema, facts and sequences, and lexical semantics), elaboration (syntactical structure, cohesion and inferences), and metacognition (text genre recognition, flexible reading strategy and detection of inconsistencies).

In addition to these linguistic skills, comprehension requires general cognitive processes, such as the executive functions (Butterfuss & Kendeou, 2018), which have been formally incorporated into theoretical models of reading, such as the 'Active View of Reading' (Duke & Cartwright, 2021). On the other hand, different lines of research indicate a consistent link between individual reading experience (volume, diversity, frequency) and text comprehension (Breadmore et al., 2019; Mol & Bus, 2011). In the following sections we will present briefly the evidence on the characteristics of reading in digital media, and the contribution of the executive functions and reading habits to comprehension.

READING COMPREHENSION IN DIGITAL MEDIA

It has been suggested that the presentation of texts on screens promotes skimming, scanning, multitasking, and attention volatility, favoring a more superficial reading strategy (Barzillai & Thomson, 2018). Recent meta-analyses have confirmed the existence of an advantage in the comprehension of expository texts (but not narrative ones) when comparing reading on paper with screens, which increases with the length of the texts or when a time limit is imposed (Delgado et al., 2018; Clinton-Lisell, 2019). Furthermore, the increase in the size of this effect in recent years has been interpreted as a consequence of the increased frequency of reading in digital media (Delgado et al., 2018). On the other hand, it has been observed that the difference between formats is reduced or disappears when interventions are made to increase the perceived importance of reading by students (Sidi et al., 2017) or to encourage deeper semantic processing (for example, by suggesting making summaries or identifying key words) (Lauterman & Ackerman, 2014). It should be noted that these studies examined reading traditional texts, or linear-structure texts, on screen, and did not include hypertext formats or web environments, which involve a series of additional competencies and cognitive demands (see Wylie et al., 2018 for a review).

THE ROLE PLAYED BY EXECUTIVE FUNCTIONS IN READING COMPREHENSION

The term “executive functions” refers to a set of cognitive processes involved in the planning, execution, monitoring, and adaptation of goal-oriented behavior (Follmer, 2018). The model of executive functions that has most influenced reading research is that proposed by Miyake et al. (2000), in which they are conceptualized as three main components or functions: inhibition, cognitive flexibility, and working memory (WM) (Butterfuss and Kendeou, 2018). WM provides a dynamic space to integrate visual text input with information evoked from long-term memory systems and allow the development of mental representations of the text at its different levels. Cognitive flexibility allows switching between different focuses of attention in the text, reading strategies, and mental levels of representation, facilitating the generation of inferences. Regarding inhibition, while it has been hypothesized to contribute to freeing up processing resources by suppressing internal or external interferences, the results have been less consistent (Follmer, 2018), and it has been interpreted that these variations depend on age and the type of inhibitory process studied (Butterfuss and Kendeou, 2018). The relative contribution of executive functions may vary depending on the characteristics of the text. In the study by Follmer and Sperling (2018), cognitive flexibility was a significant predictor of comprehension of scientific expository texts with low cohesion, while working memory predicted the comprehension of highly cohesive texts. For their part, Cartwright et al. (2020) found that general domain executive functions have a direct effect on text comprehension in university students, as well as an indirect effect, mediated by their language skills (vocabulary and reading fluency).

While empirical evidence has established the contribution of executive functions to reading comprehension in paper format (for a meta-analysis, see: Follmer, 2018), the demands that the presentation of linear texts on screen might pose to executive processes have not yet been systematically investigated. In this sense, it has been found that the study of reading digital hypertexts (which typically present a non-linear structure), or in internet environments, generates an additional cost of executive processing, linked to the challenges posed by navigation (Wylie et al., 2018).

READING HABITS AND TEXT COMPREHENSION

There is ample evidence of the link between reading experience (the amount of time, volume and/or diversity of texts read) and the ability to understand texts (see the meta-analyses by Breadmore et al., 2019; Mol & Bus, 2011). One of the most commonly used measures to objectively assess print exposure is the Author Recognition Test (ART) (Stanovich & West, 1989), a task that examines how many names of fiction (or non-fiction) authors subjects are able to recognize. Studies conducted on the Argentine university population showed that the ART is a robust predictor of reading comprehension among students (Tabullo et al., 2020, 2024). Mol & Bus (2011) found moderate to strong correlations between the score on this task and measures of text comprehension, an effect that increased with age. The results were interpreted as indicators of reciprocal causality: just as good comprehenders were avid readers, their reading experience contributed to improving their reading skills. This explanation is known as the Matthew effect (Stanovich, 1986). Several mechanisms have been proposed to explain the contribution of reading habits to comprehension: the increase in vocabulary improves lexical representations (Mol & Bus, 2011), the automatization of low-level processes, such as word decoding (Perfetti, 2007), or training in inference generation (Mani & Huettig, 2014). In the case of digital reading, it has been proposed that the growing (and increasingly earlier) exposure to screens could have a negative impact on comprehension (Delgado et al., 2018), and better performances have been found in children who prefer paper (OECD, 2021). However, a large-scale study found no influence of the frequency of digital media reading on text comprehension in adolescents (Duncan et al., 2016). Lastly, a recent meta-analysis found an interaction between the educational stage and digital reading habits: while negative effects are observed in primary school, the association becomes positive in secondary school and university (Altamura et al., 2023).

Despite the extensive evidence on the role of executive functions and reading habits on text comprehension, the contribution of these factors to screen reading has not yet been systematically examined in university students. The present study aimed to analyze the relationship between the comprehension of expository and narrative texts presented on screen, executive functions, and reading habits in university students, considering in particular their exposure to fiction (measured with an Author Recognition Test) and their favourite medium for reading for study or recreational purposes (paper, mobile phone screen, or personal computer screen).

METHODOLOGY

Design

The present research had a quantitative, non-experimental, correlational and transversal study design.

Participants

The study sample was selected using a non-probabilistic convenience sampling method. Ninety-eight first-year university psychology students from the Pontifical Catholic University of Argentina (Mendoza) participated in the study (76.8% women, Mean Age: $M = 20.6$, $SD = 5.24$ years). To verify if reading comprehension was similar between screen and paper reading medias, we compared our participants' performance with that of a different group of students, who took part in a previous study reading the same texts on paper instead of screens (control group data: *expository text group*: $N = 62$, 74.2% women, Age $M = 19.9$, $SD = 4.3$ years; *narrative text group*: $N = 56$, 69.6% women, age $M = 20.4$ years, $SD = 6.36$ years). The students comprising these control groups came from the same career in the same university and were taking the same courses than the study sample when they were evaluated, and were also similar in age ($T(211) = 0.600$, $p = .549$) and gender ($\chi^2 = 0.707$, $p = .401$). All of them completed an informed consent form, which explained that the activity was voluntary and anonymous, and that they could withdraw from the study at any time, without any negative consequence. This study was designed and conducted according to ethics normative 5344/99 of the National Council of Scientific and Technical Research, and all its proceedings were in accord with the 1975 Helsinki Declaration and its subsequent amendments.

Instruments

Expository and narrative text comprehension test (Cotton et al., 2023). A test from a previous digital reading comprehension study was applied (Cotton et al., 2023). The test consisted in reading an expository text (a science communication article titled "Mathematics, brain and dyscalculia", by Valeria Abusamra) and a narrative text (a story titled "The coffee cups", by Mario Benedetti). The narrative text was 1117 words long and told the story of a love triangle between a husband, his wife and one of his friends. The instrument INFLESZ (Barrio-Cantalejo et al., 2008) was applied to determine its reading difficulty, which was classified as "rather easy". On the other hand, the expository text was 1113 words long, and explained the links between children's brain development and mathematical skills. The text was written to make it accessible for non-specialized readers. According to the INFLESZ scale, its reading difficulty was "rather difficult". After reading each text, participants answered 12 multiple-choice questions (one correct answer and three wrong but semantically-related alternatives). These questions covered the most relevant aspects of comprehension, according to the multicomponential model. The task was administered on a PC screen through the *Google Forms* platform.

TAC Neuropsychological battery (*Tareas de autorregulación cognitiva - Cognitive Self-regulation Tasks*) (Introzzi & Canet-Juric, 2019). The following tests from the computerized neuropsychological battery were administered:

- Visual Search, which evaluates perpetual inhibition
- Fingers task, which evaluates cognitive flexibility

The visual search task requires participants to indicate the presence or absence of a target stimuli (blue square) among a variable number of distractors, pressing Z or M keyboard keys, respectively.

Performance is operationalized as the difference between mean response times between high (32 distractors) and low cognitive load (4 distractors) trials, so higher scores indicate higher cognitive costs (and therefore, worse performance).

The finger task displays a hand drawing on the left or right side of the screen, with its index finger pointing downwards (same side) or to the other side of the screen. Participants are instructed to press a key located on the same side as the hand (congruent trial) or on the opposite side (incongruent trial). Performance is operationalized as an Inverse Efficiency score (Mean response time / (1 - error proportion)), calculated over those trials where response type (ipsilateral or contralateral) and response side (left, right) are different from the previous trial.

The TAC battery has shown adequate internal and external validity in adults (Richards et al., 2021)

Running span task (Barreyro et al., 2019). We administered an adapted version of the running span task, from the computerized BIMeT-V working memory battery, to evaluate verbal working memory. The task requires participants to remember a letter sequence of variable length (presented one at a time) and to recall the last 2, 3, 4, 5 or 6 letters shown. The length of the sequence is unknown to the participant in each trial. When the word “recall” appears on the screen, the participant must input the letters in the same order through the keyboard. As the task progresses, the number of letters to be remembered increases. Performance was operationalized as the number of correctly recalled letter sequences.

Reading habits survey. An ad hoc survey was administered to examine the students’ reading habits, including: number of books in their personal library, on paper and digital formats (Likert-scale responses from 0 to 5: 0 = none, 1 = 1 to 10, 2 = 10 to 30, 3 = 30 to 50; 4 = 50 to 100, 5 = more than 100) and number of books read for recreational purposes within the last six months. The survey also asked about the weekly frequency of the following reading-related activities: web surfing (reading websites for non-study purposes, does not include social networks), social networks (Facebook, Instagram, etc.), recreational reading (novels, stories, fiction and non-fiction), study reading (Likert-scale responses from 0 to 6: 0 = does not do it / almost does not do it on a weekly basis, 1 = a couple days a week, 2 = one hour per day, 3 = 1-2 hours per day, 4 = 2-3 hours per day, 5 = 3-4 hours per day 6 = 4 hours or more per day). In addition, participants indicated their preferred reading media for recreational and study purposes (paper, PC or laptop screen, smartphone). This survey was based on a previous study conducted on the local university population. (Tabullo et al., 2024).

Author Recognition Test. To evaluate fiction print exposure, a local version of the Author Recognition Test (ART) that had been designed and validated for the national context, and previously applied in the local university population, was used (Tabullo et al., 2018; 2020). This task was based on the most widely applied and validated instrument to measure fiction literature exposure, the Author Recognition Test designed by Stanovich and West (1989), which has proven to be a consistent predictor of reading comprehension and other language skills (Mol y Bus, 2011). The task consists in identifying the names of ten literary fiction authors (including Literature Nobel Prize winners, such as Albert Camus, Haruki Murakami or Mario Vargas Llosa) from a list that includes another ten fake author names. Performance is calculated as the number of correctly identified authors, minutes the number of incorrectly selected fake author names.

Procedure

The task was conducted in the university’s computer room, during class hours. The students were informed that the purpose of the study was to examine the relationship between reading texts on screen and cognitive abilities. The students performed the tasks in the following order: text comprehension task,

TAC battery tests, verbal working memory task, reading survey, and ART. The study was conducted in a single session and lasted approximately one hour. The comprehension test, the survey, and the author recognition test were administered via the Google Forms platform.

Data Analysis

To examine if reading comprehension was similar between paper and screen formats, the percentage of correct responses for each text was compared between the study and control groups with a Students' T test. An exploratory analysis of the associations between study variables was conducted with Spearman correlations. An ANOVA was applied to examine differences in reading comprehension by gender and text genre, and MANOVAs were conducted to examine performance differences according to the preferred recreational and study reading media. The contribution of executive functions and reading habits to expository and narrative text comprehension was analyzed through hierarchical multiple linear regression analyses, including the following predictors in successive steps of the model: demographic variables (age, gender), verbal WM, inhibition and flexibility scores, ART scores and those reading habit variables with the most significant associations with reading comprehension, according to the correlation analysis. In the regression analysis, assumptions of normality (non-significant Shapiro-Wilk test), homocedasticity and linearity assumptions (visual inspection of residual plots) were verified. The error independence assumption was confirmed using the Durbin-Watson coefficient ($1.91 < DW < 2.06$), and variance inflation factor analysis did not indicate the presence of multicollinearity risks ($1.05 < FIV < 1.20$). Statistical analysis was conducted using JAMOVI software.

RESULTS

Descriptive statistics and associations between study variables

Descriptive statistics of study variables are synthesized in Table 1. To examine if text comprehension on screens was similar to paper, the percentage of correct responses was compared between the study and control groups with Students T tests. No comprehension differences were found for the expository ($T(158) = -0.334, p = .738$) or narrative text ($T(152) = -0.427, p = .670$) as a function of format (Table 2). Considering the Shapiro-Wilk test did indicate a violation of the normality assumption in this case ($W = .968, p = .001$), the Mann-Whitney U-test was applied to verify the T-test results. Once again, we did not find significant differences (*Expository text*: $U = 2920, p = .678$; *Narrative text*: $U = 2682, p = .756$).

Table 1

Descriptive Statistics of Study Variables

	M / Med	SD / IQR	Minimum	Maximum
Expository	55.61	17.25	25.000	100.00
Narrative	44.24	18.00	8.333	91.67
WM	4.86	2.44	0.500	12.00
Inhibition	566.99	299.99	71	2085
Flexibility	10.31	3.29	4.920	26.32
Libpaper	2.00	2.00	0.000	5.00
Libdigital	1.00	1.00	0.000	5.00
Book6m	2.00	2.50	0.000	10.00
SocialN	4	2.00	0	6
Web	3	2.00	0	6

	M / Med	SD / IQR	Minimum	Maximum
Recreational	2	3.00	0	6
Study	3	1.00	0	6

Note: Mean (M) and standard deviations (SD) of continuous variables (reading comprehension and executive functions); and median (Med) and interquartile range (IQR) of ordinal variables (reading habits) are shown. Expository: % of correct responses in the expository text. Narrative: % of correct responses in the narrative text. WM: verbal working memory (number of correct responses). Inhibition: visual search task score (response times difference between 32 and 4 distractor conditions). Flexibility: Fingers task score (inverse efficiency). Libpaper: Amount of paper books in personal library. Libdigital: number of digital books in personal library. Book6m: number of books read within the last 6 months. SocialN: weekly frequency of social network use. Web: weekly frequency of web surfing. Recreational: weekly frequency of recreational reading. Study: weekly frequency of study reading.

Table 2

Percentage of success in the text comprehension task by reading format

Text	Medium	N	M	SD
Expository	Screen	98	55.4	17.4
	Paper	62	56.3	18.2
Narrative	Screen	98	43.9	17.9
	Paper	57	45.2	17.9

Note: Mean (M) and standard deviations (SD) of the % of correct responses in the reading comprehension task are presented for those groups of subjects who read the texts on screens or paper.

Reading comprehension scores for both texts were compared with a text × gender repeated measures ANOVA with age as a covariate. A significant interaction between gender and text type was found ($F(1,92) = 7.345, p = .008$). Men obtained significantly better scores in the expository ($M = 56.4\%, DE = 16.3\%$) text compared to the narrative text ($M = 36.1\%, DE = 16.5\%$) ($p = .018$), while women outperformed men in the latter ($M = 46.4\%, DE = 18.4\%$) ($p = .021$).

Spearman correlations matrix is shown in Table 3. Expository text comprehension was associated with: WM ($\rho(96) = .247, p = .016$), cognitive flexibility ($\rho(96) = -.214, p = .035$) and the number of digital books ($\rho(96) = .229, p = .025$). Narrative text comprehension was associated with: working memory ($\rho(96) = .247, p = .040$), ART scores ($\rho(96) = .348, p < .001$), number of recently read books ($\rho(96) = .209, p = .042$) and the frequency of recreational reading ($\rho(96) = .215, p = .037$).

Table 3

Matrix of Spearman correlations among study variables

	1	2	3	4	5	6	7	8	9	10	11	12
1. Expository	—											
2. Narrative	0.427	***	—									
3. WM	0.236	*	0.231	*	—							
4. Inhibition	0.125	0.002	-0.096	—								
5. Flexibility	-0.245	*	-0.105	-0.068	-0.139	—						
6. Libpaper	0.192	0.077	0.094	0.026	-0.14	—						
7. Libdigital	0.215	*	0.156	0.222	*	-0.223	*	0.083	0.256	*	—	

	1	2	3	4	5	6	7	8	9	10	11	12
8. Book6m	-0.029	0.228 *	-0.02	-0.102	0.211 *	0.21	* 0.484	*** —				
9. SocialN	-0.051	0.067	0.028	0.178	-0.146	-0.154	-0.266 **	-0.087	—			
10. Web	-0.108	0.103	0.171	-0.019	0.119	-0.064	0.209 *	0.173	0.289 **	—		
11. Recreational	-0.07	0.232 *	0.082	-0.13	0.149	0.183	0.396 ***	0.557 ***	0.05	0.178	—	
12. Study	-0.047	0.045	0.035	0.053	0.15	0.15	0.114	0.093	0.143	0.13	0.355 ***	—

Note: Expository: % of correct responses in the expository text. Narrative: % of correct responses in the narrative text. WM: verbal working memory (number of correct responses). Inhibition: visual search task score (response times difference between 32 and 4 distractor conditions). Flexibility: Fingers task score (inverse efficiency). Libpaper: Amount of paper books in personal library. Libdigital: number of digital books in personal library. Book6m: number of books read within the last 6 months. SocialN: weekly frequency of social network use. Web: weekly frequency of web surfing. Recreational: weekly frequency of recreational reading. Study: weekly frequency of study reading.

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

Regarding the preferred reading medium for studying, most of the students chose the computer (58.2%), paper came in second place (32.7%) and the smallest proportion used the smartphone (9%). In the case of recreational reading, most preferred paper (50%), in second place, smartphone (29.6%) and then the computer (9.2%), while the remaining 10.2% answered that they did not read for recreational purposes. To examine the association between preferred reading medium and text comprehension performance, subjects were classified in one of the following groups: reading on paper for studying ($n = 32$) vs reading on computers ($n = 57$), and recreational reading on paper vs smartphones ($n = 29$). We decided to choose the more frequent category instead of collapsing both screen reader groups, since previous studies reported differences in reading comprehension when comparing smartphones and computer media (Alrizq et al., 2021; Cotton et al., 2023).

Regression analysis of reading comprehension

Expository text comprehension. Explained variance increased with the inclusion of flexibility ($\Delta R^2 = .051, p = .031$) and WM ($\Delta R^2 = .047, p = 0.034$) ($R^2 = .071, F(5,86) = 2.397, p = 0.044$), while ART and the number of digital books did not have significant effects (see Table 4). Expository text comprehension improved with flexibility scores ($\beta = -.220, p = .034, IC [-0.424, -0.017]$) and WM ($\beta = .228, p = .029, [0.024, 0.433]$).

Narrative text comprehension. Explained variance increased with the inclusion of WM ($\Delta R^2 = .075, p = .007$) and ART ($\Delta R^2 = .057, p = .015$) ($R^2 = .165, F(6,85) = 4.00, p = 0.001$), while no effects were observed for other EFs or the number of books read recently (see table 4). Narrative text comprehension improved with WEM ($\beta = .273, p = .006, IC [0.079, 0.467]$) and ART scores ($\beta = .247, p = .015, IC [0.050, 0.442]$), and was lower among men ($\beta = -.570, p = .017, IC [-1.035, -0.106]$).

Table 4

Regression analysis of reading comprehension scores

Text	Model	Predictor	R^2	F	ΔR^2	F
Expository	1	Age, gender	0.008	0.381		
	2	WM	0.028	1.86	0.051	4.78 *
	3	Inhibition	0.032	1.76	0.015	1.44
	4	Flexibility	0.071	2.40	* 0.047	4.65 *
	5	ART	0.094	2.58	* 0.032	3.17

Text	Model	Predictor	R ²	F		Δ R ²	F	
	6	Libdigital	0.106	2.53	*	0.021	2.08	
Narrative	1	Age, gender	0.044	3.11	*			
	2	WM	0.112	4.81	**	0.076	7.74	**
	3	Inhibition	0.105	3.65	**	0.003	0.29	
	4	Flexibility	0.114	3.35	**	0.019	1.97	
	5	ART	0.165	4	***	0.057	6.22	*
	6	Book6m	0.155	3.39	**	0.000	0.01	

Note: Expository: % of correct responses in the expository text. Narrative: % of correct responses in the narrative text. WM: verbal working memory (number of correct responses). Inhibition: visual search task score (response times difference between 32 and 4 distractor conditions). Flexibility: Fingers task score (inverse efficiency). Libdigital: number of digital books in personal library. Book6m: number of books read within the last 6 months.

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

Effects of preferred reading media on text comprehension

Preferred reading media for studying. A significant main effect of preferred reading media for studying was found ($Wilk's\lambda = .886, F(2,88) = 4.27, p = 0.017$). Expository text was better among students who preferred studying on computer screens ($M = 59.5\%, SD = 43.6\%$) than in those who prefer studying on paper ($M = 51.2\%, SD = 16.9\%$) ($F(1, 89) = 5.066, p = .027$), while no significant differences were observed in narrative text comprehension ($F(1, 89) = 0.265, p = .608$). This effect was still significant after controlling for gender, flexibility and WM as covariates ($Wilk's\lambda = .906, F(2,79) = 4.12, p = .020$).

Preferred reading media for recreational purposes. No effects of preferred recreational reading media on reading comprehension were observed ($Wilk's\lambda = 0.996, F(2,75) = 0.15, p = .860$).

DISCUSSION

This study has been the first to analyze and compare the joint contribution of the executive functions and reading habits to the comprehension of expository and narrative texts read on screen, in university students. These texts were considerably difficult for the students, however their performance was not significantly lower than those of students that completed the task on paper. When EFs were considered, WM contributed to the comprehension of both texts, while cognitive flexibility was a specific predictor of the expository text. Among the variables describing reading habits, exposition to literary fiction (ART score) was the main predictor of narrative text comprehension. In addition, we found that those students who preferred studying on screens performed better in the expository text than those who preferred doing it on paper, while no differences were observed based on the preferred medium for recreational reading. These findings are discussed below.

The role of executive functions in the comprehension of expository and narrative texts on screen

In accordance with previous studies of reading on paper (Butterfuss & Kendeou, 2018; Follmer, 2018) and digital hypertexts (Wylie et al., 2018), the comprehension of linear expository and narrative texts on screen was significantly associated with the executive functioning of university students. In particular, a general contribution of WM to both texts, and a specific contribution of flexibility to the expository text, were found.

The contribution of WM to the comprehension of both types of text is consistent with theoretical models (Rayner & Reichle, 2010) and previous evidence. Follmer's meta-analysis (2018) indicated that this effect was significant across all age ranges considered (children, adolescents, adults). WM provides a workspace for integrating current input with the ongoing mental representation of the text, and the information recalled from long-term memory. Additionally, the updating component of WM (assessed in our work through the *running span* task) is an even stronger predictor of comprehension than measures more closely linked to WM capacity (such as digit span), since it considers the ability to sustain relevant information and to actively exclude the irrelevant. WM updating contributes to building coherent representations of the text (Butterfuss & Kendeou, 2018). Furthermore, this updating component could be more intimately linked to specific comprehension processes, such as inference generation (Potocki et al., 2017). Lastly, we cannot dismiss the possibility that the observed contribution of WM is totally or partially mediated by linguistic skills, such as vocabulary or reading fluency, as has been observed in adults (Georgiou & Das, 2016), adolescents, and children (Spencer et al., 2020; Ober et al., 2019).

The contribution of flexibility to the comprehension of expository texts is also consistent with theory (Butterfuss & Kendeou, 2018) and previous evidence (Follmer, 2018). Various studies have identified flexibility as a predictor of comprehension in children (Kieffer et al., 2013), adolescents (Kieffer et al., 2021), and adults (Georgiou & Das, 2016). Specific associations with expository text have also been reported in children (Wu et al., 2020), and adults (Follmer & Sperling, 2018). In addition, a measure of flexibility applied to the processing of phonological and semantic aspects of words explained an additional portion of the variance of text comprehension, when compared to general domain EF measures in adults (Cartwright et al., 2020). Flexibility is implied in inference generation, and it has been observed that inferential comprehension processes are consistently more difficult in expository texts, across all ages (see Clinton-Lisell' meta-analysis, 2019). A study in adults showed that cognitive flexibility was a better predictor of comprehension of scientific texts (above other EFs) when they had lower referential cohesion (Follmer & Sperling, 2018). Moreover, and similarly to WM, we cannot rule out the possibility of a total or partial mediation of this flexibility effect by linguistic skills, as seen in previous studies (Cartwright et al., 2020; Ober et al., 2019; Spencer et al., 2020).

Unlike what was observed in other works (Abusamra et al., 2020; Demagistri et al., 2014), we did not find effects of inhibition on the comprehension of either text. This difference could be due to these studies using a specific measure of inhibition of verbal responses (Hayling test), while we examined inhibition at the perceptual level (visual selective attention). Furthermore, it has been proposed that the inconsistencies found in the contribution of inhibition could be due to the variability of measures and processes considered, as well as verbal specificity of the processes (Follmer, 2018).

Effects of reading habits in the comprehension of expository and narrative texts

Despite the low performance of the sample, no differences were found when they were compared to the controls who read on paper. In the case of the expository text, this does not align with what was observed in the meta-analyses by Delgado et al. (2018) and Clinton-Lisell (2019). It has been proposed that screens promote a more superficial mode of reading, less focused and more biased by overconfidence and lack of self-monitoring. On the other hand, this effect is more clearly observed when longer texts are examined (Singer & Alexander, 2017a; 2017b) or when working under time constraints (Ackerman & Lauterman, 2012), which could explain the absence of differences in our case, since we did not introduce these conditions. Additionally, another study conducted in adults (Ball & Hourcade, 2011) failed to find any differences in comprehension between reading mediums.

In the analyses of reading habits, significant correlations were observed between measures of: exposure to written fiction, frequency of recreational reading, recent reading volume, and comprehension of narrative text on screen, while the regression analysis pointed to TRA as the main predictor of performance. There is ample evidence that reading fiction experience measured through TRA is a robust predictor of text comprehension throughout life (Breadmore et al., 2019; Mol & Bus, 2011). As most of

these works have examined reading on paper, our results allow the extension of these conclusions to the comprehension of narrative texts read on screens. Regarding the exclusivity of the observed advantage for narrative texts, it is possible that a higher previous experience with fiction literature facilitates the comprehension of characters, actions, events, and context of the presented narrative, thereby contributing to the construction of the situation model of the text (Kintsch, 1988). It is worth noting that no digital media reading frequency effects (social networks, web browsing, digital library size) were found for narrative texts. In the case of the expository text (which dealt with developmental psychology), the specificity of its demands in terms of technical vocabulary and previous knowledge about the subject may have limited the contribution of fiction exposure to performance.

Even though we have not found consistent effects of reading habits on expository text comprehension, we did observe interesting effects of reading medium: those students accustomed to studying on screens exhibited a better performance. At first sight, this result might seem contrary to the negative effect of screens for expository text comprehension observed in the meta-analyses by Delgado et al. (2018) and Clinton-Lisell (2019). On another hand, it has been observed that the difference between digital and paper formats diminishes or disappears when interventions are made in order to increase the perceived importance of reading by students (Sidi et al., 2017) or when a deeper semantic processing is encouraged (e.g., suggesting summarizing or identifying keywords) (Lauterman & Ackerman, 2014). It could then be argued that those students accustomed to studying the contents of the university curriculum on screen (computer) could have more developed compensatory strategies (attentional focus, deep processing, strategic reading), turning out more successful when performing comprehensive reading of an expository text in this format. Students accustomed to studying on paper, on the other hand, might experience the opposite effect: greater difficulties in identifying and retaining relevant information due to the properties of the screen format that hinder the depth of reading. This familiarity or adaptation mechanism to the medium would be similar to the role of internet navigation skills as predictors of comprehension of digital hypertexts (Hahnel et al., 2016).

STUDY LIMITATIONS

Among the limitations of the present study, we must point to the relatively small sample size and low proportion of men. In addition, voluntary participation suggests possible selection bias. Regarding the expository text, students' previous knowledge of the subject was not controlled, but all the students were in their first year of degree and none of them had yet studied developmental psychology or another relevant subject (in the case of the narrative text, on the other hand, none had read the story previously). Furthermore, reading times and their possible contribution to comprehension performance were not systematically evaluated. Self-reporting measures of reading frequency (for screen activities, recreational reading, or study reading) were used, and could be more accurate if complemented with more objective variables. Other possibly relevant variables, such as text interest or motivation, were not considered either. Finally, although a control group was included in order to verify that the reading performance on screens was similar to that on paper, future research should compare the contribution of EFs and reading habits to reading texts on paper and screen, with the purpose of detecting potential differences in the cognitive processes involved.

CONCLUSION

Different contributions of EFs and reading habits to the comprehension of expository and narrative texts on screen were found. Both the general association with working memory and the specific role of flexibility in the expository text, as well as the effect of fiction exposure in the narrative text are consistent with previous studies of reading on paper. No effects of digital media reading frequency (social network, web) on comprehension were found. The effect of the preferred reading medium for study on the comprehension of expository texts on screen is interesting and relevant for the academic field, so it should be replicated in a larger sample and analyzed more deeply in future research. Likewise, considering

the difficulties of reading found at the secondary level of education in the Latin American and local contexts, the comparative study of the cognitive demands of reading on paper and digital mediums in university students and adolescents could inform decision-making; as well as pedagogical interventions aimed at compensating this deficit and improving academic performance. Lastly, it is recommended to try and replicate these findings on larger samples, with a wider age range, and better representation of both genders in order to strengthen our conclusions.

AUTHOR CONTRIBUTIONS

Ángel Javier Tabullo: Project administration; Formal analysis; Conceptualization; Data curation; Writing - original draft; Writing - review & editing; Investigation; Methodology; Resources; Software; Supervision; Validation; Visualization.

Enrique-Salvador Pulifiato-Hamann: Writing-original draft; Writing - review & editing; Research; Methodology; Resources; Software.

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