

## **COMPREHENSION OF ACADEMIC TEXTS: ROLE OF EXECUTIVE FUNCTIONS AND VOCABULARY**

### **COMPRENSIÓN DE TEXTOS ACADÉMICOS: ROL DE LAS FUNCIONES EJECUTIVAS Y EL VOCABULARIO**

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**ABSTRACT:** Comprehension of academic texts is often a complex activity for university students during their first year of studies. This activity may be associated with a higher cognitive demand when reading in digital support and in the presence of distractors. Thus, the general objective of this research was to analyze the role of four executive functions (inhibition, goal setting, working memory and processing speed) in the comprehension of academic texts, together with the role of vocabulary. 62 first-year university students participated in an experimental study in which the effect of inhibition and goal setting on academic text comprehension was analyzed. To determine the effect of the distractor on reading comprehension, an eye tracker was used during reading. The experimental task was complemented with the measure of working memory, processing speed and vocabulary. From the results we conclude that inhibition and goal setting influence comprehension when reading is interrupted by distractors. In addition, we conclude that working memory and processing speed are not related to comprehension, in contrast to vocabulary which correlates positively and significantly with the comprehension of academic texts in first-year university students.

**KEYWORDS:** reading comprehension, academic text, executive functions, vocabulary, university students.

**RESUMEN:** La comprensión de textos académicos suele ser una actividad compleja para los estudiantes universitarios durante su primer año de estudios. Esta actividad puede estar asociada a una mayor demanda cognitiva cuando se lee en soporte digital y en presencia de distractores. Así, el objetivo general de esta investigación fue analizar el papel de cuatro funciones ejecutivas (inhibición, establecimiento de objetivos, memoria de trabajo y velocidad de procesamiento) en la comprensión de textos académicos, junto con el papel del vocabulario. 62 estudiantes universitarios de primer año participaron en un estudio experimental en el que se analizó el efecto de la inhibición y el establecimiento de objetivos en la comprensión de textos académicos. Para determinar el efecto del distractor en la comprensión, se utilizó un rastreador

ocular durante la lectura. La tarea experimental se complementó con medidas de memoria de trabajo, velocidad de procesamiento y vocabulario. De los resultados se concluye que la inhibición y el establecimiento de objetivos favorecen la comprensión cuando la lectura es interrumpida por distractores. Además, se observa que la memoria de trabajo y la velocidad de procesamiento no correlacionan con la comprensión, en contraste con el vocabulario, que correlaciona positiva y significativamente con la comprensión de textos académicos en estudiantes universitarios de primer año.

**PALABRAS CLAVE:** comprensión lectora, textos académicos, funciones ejecutivas, vocabulario, estudiantes universitarios.

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## INTRODUCTION

Comprehension of a written text is an intentional and voluntary activity in which readers behave according to the characteristics of the text, topic, the purpose of the reading and the type of task (León 2004). The type of task is determined by the instructions, which play a fundamental role in the processing of a text, given that they allow readers to focus attention on segments of the text that are relevant for the development of specific tasks (Cerdán and Marín 2019; Cerdán et al. 2019; Jian 2018; León et al. 2019). From this perspective, and from a multidimensional approach to reading, successful comprehension of a written text requires both elementary linguistic skills (e.g., decoding, fluency) and the use of high-level skills that, according to the literature, would be involved in the deep understanding of concepts and ideas of a text (Alexander 2005; Alexander and DRL 2012; Bohn-Gettler and Kendeou 2014; Kendeou 2014; Kintsch 1998). Within these high-level skills we find cognitive processes that, as a whole, are called executive functions, among which are working memory, processing speed, goal setting, and inhibition.

Executive functions are a set of high-level dissociable cognitive processes that operate in an interrelated manner and are involved in the voluntary control of behaviors, emotions, and thoughts according to specific goals (Anderson 2002; Diamond 2013; Friedman et al. 2016). According to studies developed in recent decades, executive functions are a source of individual differences in reading comprehension in teenagers (Corso et al. 2016; Potocki et al. 2017) and specifically among university students (Butterfuss and Kendeou 2018; Follmer and Sperling, 2018, 2019; Georgiou and Das 2015, 2016, 2018); Kendeou et al. 2016).

Respect to working memory, numerous studies have revealed the existence of a statistically significant correlation between this executive function and reading comprehension, even when controlling for basic reading skills (e.g., reading fluency) (Bohn-Gettler and Kendeou 2014; Carretti et al. 2009; Christopher et al. 2012; Follmer and Sperling 2018; Ober et al. 2019; Peng et al. 2018; Perfetti and Stafura 2014). However, the role of working memory in comprehension appears to vary by reading experience. Studies suggest that working memory as a central executive domain would be involved in early reading acquisition, whereas a verbal component of working memory would be more strongly implicated in later reading performance as readers gain more experience in handling the written code (Peng et al. 2018). Given that this executive function may be strongly and significantly correlated with other measures associated with language ability such as, for example, lexical knowledge (Van Dyke et al. 2014), this study included a measure of vocabulary. In this respect, numerous studies evidence the relationship between vocabulary and reading comprehension, considering this variable as a strong predictor of reading comprehension directly, i.e., through vocabulary amplitude; and indirectly, as a predictor of the ability to make inferences during reading (Freed et al. 2017; Guerra and Kronmüller 2019; Oakhill and Cain 2012; Perfetti 2007; Perfetti and Stafura 2014; Ribeiro et al. 2016; Van Dyke et al. 2014).

The speed that a person can complete a cognitive task is referred to as processing speed (Rosas et al. 2014). This executive function has been insufficiently explored in adult readers who perform well on reading tasks (Christopher et al. 2012; Freed et al.

2017). Nevertheless, this variable is thought to be important because reading is a sequential and speed-dependent activity: words are decoded one at a time and must be integrated into a mental representation of the sentence before the verbal trace of preceding words begins to decay (Christopher et al. 2012). In turn, the speed of information retrieval through retrieval cues is also relevant for comprehension (Van Dyke et al. 2014), therefore this variable could be related to working memory (Borella and de Ribaupierre 2014; Borella et al. 2011). The present study aims to provide further evidence on the relationship between this variable and academic text comprehension.

An important part of the learning that takes place in and out of academic contexts is sustained by the successful comprehension of written texts (Bohn-Gettler and Kendeou 2014; Parodi 2011; Van den Broek and Kendeou 2008). However, students beginning university studies presents reading difficulties in first language (L1) that can complicate learning (Makuc and Larrañaga 2015; Neira et al. 2014; Ramírez and Riffo 2014; Riffo and Contreras 2012). In addition, the change from reading texts on paper to reading on digital devices, such as computers, tablets and smartphones, generates important changes in the contexts in which reading tasks are developed, where diverse stimuli compete (Salmerón and Delgado 2019; do Amaral and Braga 2022) that tend to generate disorientation and superficial processing of the text (Piovanio et al. 2018). Contexts in which diverse stimuli compete generate a high cognitive load for readers (Wilcockson et al. 2019), therefore, the activation of attentional control resources is required to focus attention according to the reading objective and ignore distractors. This provides evidence of the effects of inhibitory control on text processing (Lu et al. 2017; Gaspelin et al. 2012; Wilcockson et al. 2019), which would allow inferring a relationship between inhibition ability and text comprehension. Indeed, a greater ability to ignore distractors is associated with higher performance on the Stroop test (Rozek et al. 2012). Therefore, the present study used distractors as a measure of inhibition ability in a digital reading context.

One approach to access cognitive processing during reading is to use an eye-tracker. The eye-tracking technique consists of the presentation of a text, object, or

image on a screen while eye movements are recorded during the reading process. The object of interest, which for the purposes of this research was a distractor, is called the area of interest. To conduct a reliable analysis of cognitive processing during reading, different measures are considered, e.g., first fixation duration, gaze duration, regressions, saccade length, among others (Mason et al. 2015; Penttinen et al. 2012; Radach et al. 2008; Raney et al. 2014; Rainer 2009; Scrimin and Mason 2015). Considering empirical evidence and theory, the measure selected to explore the role of inhibition in reading through the presence of distractors was gaze duration, which accounts for the time in which the subject looks at the area of interest (distractor) from the incoming saccade to the outgoing saccade, including all fixations that occur in interest.

The use of eye movement recording to explore the ability to inhibit in the presence of a distractor has been employed in previous studies to preserve the ecological validity of the assessment in reading situations in which the reader is required to keep attention focused on processing the text while trying to inhibit gaze or attention to the competing stimulus (Wilcokson et al. 2019). According to findings, ignoring distractors is a cognitively demanding task and appears to account for inhibitory control ability (Gaspelin and Luck 2018; Rozek et al 2012; Wilcokson et al. 2019).

The present study is based on a functional perspective of reading, linking two constructs (executive function and reading comprehension) through two theoretical models: the Executive Function model proposed by Anderson (2002), which considers goal setting in one of its dimensions; and the Goal-Focusing model of reading (McCrudden and Schraw 2007), which accounts for a functional approach to reading in academic contexts, specifically, reading texts for learning. Importantly, the Goal-Focusing model allows us to complement one of the classic approaches to comprehension: the Construction-Integration model (Kintsch 1988; Kintsch and van Dijk 1978), by examining the role of relevance instructions in the comprehension of academic texts.

The general objective of the present research was to analyze the role played by the executive functions inhibition, goal setting, working memory and processing speed on the comprehension of academic texts in first-year university students. Additionally,

the study aimed to determine the relationship between vocabulary and academic text comprehension, to explicitly contemplate the linguistic domain in the study through a measure of lexical knowledge. An experimental study was developed to determine the effect of inhibition and goal setting on academic text comprehension; and neuropsychological assessments of the working memory, processing speed and vocabulary were applied.

## **1. METHOD**

### **1.1. PARTICIPANTS**

The sample size was calculated using G\*Power 3 software (Faul and others 2007). 62 university students native Spanish speakers (mean age= 18.21 years; age range = 17-20 years; 64.5% women) participated in the study. All participants declared to have no previous academic experience in higher education and normal or corrected to normal vision. All of them read and signed an informed consent form. As compensation for their participation, each participant was given a gift consisting of highlighter pencils.

### **1.2. PROCEDURE**

All participants completed two sessions. The first session corresponding to the experiment was executed individually in a laboratory environment. Participants were assigned to each group at random. Each participant read two texts, one with a distractor and the other without. The texts were presented segmented by paragraphs on a monitor. To advance in the reading the participant had to press a key. There was no time limit for the execution of the task. At the end of the reading of each text, the participant completed a comprehension test of the text read, which was applied in paper and pencil format, with an indefinite time for execution. The complete procedure (reading of texts and comprehension tests) lasted between 45 and 60 minutes per participant. In the second session, participants completed a battery of tests on working

memory, processing speed and vocabulary. The tests were administered by a psychologist, individually, in a quiet space without distractions, following the standardized order of administration referred to in the administration manual. The session lasted between 30-45 minutes.

### 1.3. EXPERIMENT DESIGN

The experiment was developed using a mixed factorial design of 2x2 (Balluerka and Vergara, 2002). The intra-subject factor was the inhibition variable and the inter-subject factor, goal setting (from the instructions). The first factor originated two experimental conditions (reading with distractor and reading without distractor), while the second factor originated two experimental groups (group with relevance instructions and group without relevance instructions) (Table 1).

**Table 1.** Experimental conditions

Group with relevance instructions	Group without relevance instructions
Text with distractor	Text with distractor
Text without distractor	Text without distractor

### 1.4. TASKS

Four experimental conditions were originated. Each participant was randomly assigned to a group (with or without relevance instructions) and completed two experimental tasks (reading with and without distractors). To evaluate the comprehension of academic texts, a reading comprehension test was applied to each text read immediately after finishing the reading.

The texts used for experimental tasks were extracted from a validated and standardized test to evaluate reading comprehension in a population that is concluding



their secondary education. Text 1 contains 559 words and text 2 contains 634 words. In both texts, the expository sequence predominates and a specialized topic on Natural and Social Sciences is explained using continuous and discontinuous text segments (graphics). Two distractors were used to assess the effect of inhibition on reading comprehension. The distractors were selected from the result of a brief pilot study and appeared as pop-up in different screen positions (left, right) and with different text segments (paragraph, graphic) (Figure 1). As a measure of inhibition, the glance duration at the distractor was considered (Ramírez-Peña et al. 2022).

To increase the probability of interference during reading, two distractors were used that were different in content, but equivalent in structure. Distractor A reported on the case of a three-year-old girl whose IQ surpassed Einstein's; distractor B, on a new technology to optimize the wifi signal at home (Figure 1).



**Figure 1.** Pop-up during the reading of a graph and a paragraph.

The instructions were manipulated to evaluate the effect of goal setting on reading comprehension. One group was exposed to relevance instructions before reading and the other group was exposed only to a general instruction indicated that did not provide concrete clues about the reading task (Table 2).

**Table 2.**

Manipulation of the variable goal setting through instructions.

With instructions of relevance	Without instructions of relevance
Read the text below to answer comprehension questions at the end of the reading.	Read the following text with attention
What is the purpose of population growth?	
What is environmental resistance?	
Why are bacteria referred to in the text?	
What are the characteristics of the logistic model of population growth?	
What is the author's purpose of the text?	
For reading graphs consider the following questions:	
What function do the graphs serve in the text?	
What information does each graph provide?	

## 2. MEASURES INDIVIDUAL DIFFERENCES

### 2.1. ACADEMICS TEXT COMPREHENSION

Ten multiple choice questions were used to assess comprehension of each text presented during the experimental task, all extracted from the standardized Lectum 7 test, form A ( $\alpha=.87$ ) and form B ( $\alpha=.83$ ). The reliability index of the parallel forms is 0.77. The questions are based on a psycholinguistic model for assessing reading comprehension that includes three dimensions of reading comprehension (textual, pragmatic and critical) and corresponds to questions with explicit and implicit answers (Véliz and others 2013). The dependent variable was operationalized as the sum of the raw scores obtained in the comprehension test of each text (text with distractor and text without distractor).

## 2.2. WORKING MEMORY, SPEED PROCESSING AND VOCABULARY

Participants was evaluated using the Weschler Adult Intelligence Scale subtest, fourth edition (WAIS-IV) (Weschler 2008) standardized for the Chilean population (Rosas et al. 2014). The evaluation was applied by a psychologist trained in the application of the Weschler scale.

**Digit span:** this is one of the central subtests for assessing the working memory index. It is a task in which subjects are asked to operate with simple verbal stimuli in three conditions: retention of digits in direct order, retention of digits in reverse order, and retention of digits in sequence. This test measures verbal working memory, encoding and short-term memory.

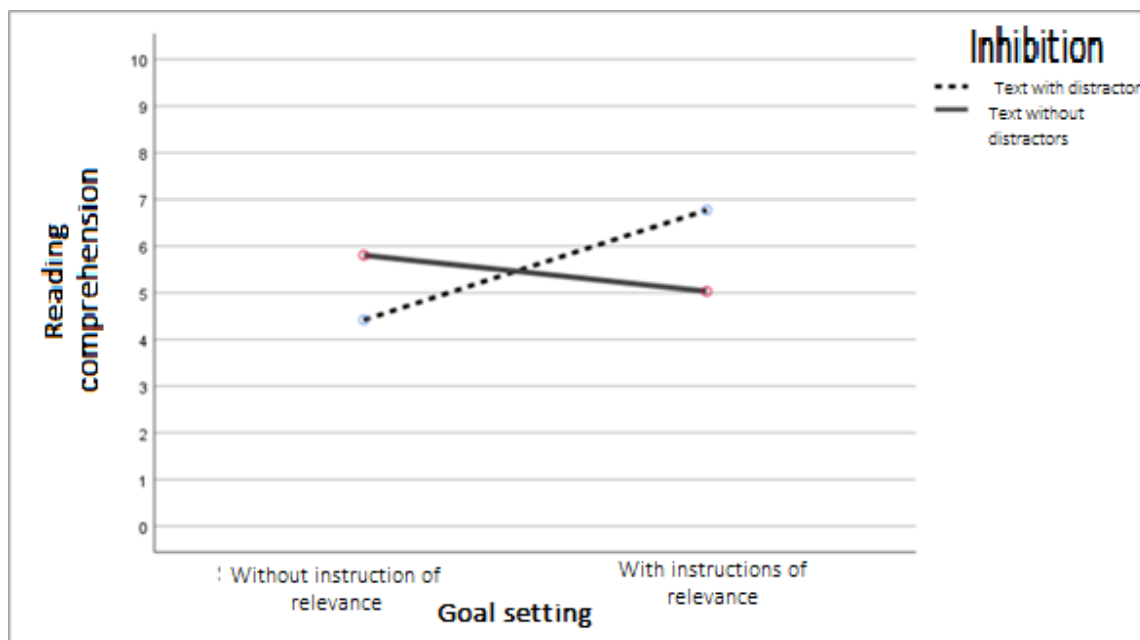
**Symbol search:** is one of the central subtests used to evaluate the processing speed index. It is a task that operates with abstract stimuli that are presented visually. The subject examines two groups of symbols: a target group and a search group. The task consists of examining the search group and pointing out whether any of the symbols match those in the target group. This test measures processing speed in the face of nonverbal material, focusing processes and attention maintenance.

**Vocabulary:** this is one of the central subtests used to evaluate the verbal comprehension index. In this task, 27 items are presented in oral form that the subject must define. This test measures lexical knowledge, verbal conceptualization and evocation of information from semantic memory.

## 3. RESULTS

An analysis of variance (mixed ANOVA) was conducted after checking the assumptions of normality, homocedasticity and sphericity. We analyzed the effect of group factors (with or without relevance instructions), reading condition (text with distractors, text without distractors), and interaction. The inter-subject factor was group and the intra-subject factor was reading condition. The repeated measures factorial ANOVA test

indicates that there is a significant interaction between the presence of distractors during reading and group comprehension of an academic text  $F(1,60) = 28,165$ ,  $p < .01$ ,  $\eta^2 = .319$  (Figure 2).



**Figure 2.** Effect of inhibition and goal setting on academic text comprehension

Specifically, in the non-distracting condition, having or not having instructions before reading a text does not produce statistically significant differences ( $M = 5.03$ ,  $DE = .39$ ;  $M = 5.81$ ,  $DE = .39$ ; respectively)  $F(1,60) = 1.95$ ,  $p > .05$ . However, in the condition with distractors, having instructions ( $M = 6.77$ ,  $DE = .30$ ) facilitates performance on the task  $F(1,60) = 30.887$ ,  $p < .01$ ,  $\eta^2 = .340$  compared to those students who were not exposed to instructions before reading ( $M = 4.42$ ,  $DE = .30$ ).

For the analysis of the variables working memory, processing speed and vocabulary, the raw score obtained by each participant in the above-mentioned tests was considered (Table 3).

**Table 3**

Individual differences: descriptive statistics and normality test

Measure	Mean Score (SD)	Median score	Min. score	Max. score	Skewness (SE)	Kurtosis (SE)	Kolmogorov- Smirnov (Sig.)	Shapiro-Wilk (Sig.)
Working Memory	26.02 (4.04)	25	18	37	.577 (.304)	.156 (.599)	.132 (.009)	.964 (.063)
Speed processing	30.81 (6.93)	30	17	49	.292 (.304)	-.413 (.599)	.079 (.200)	.984 (.579)
Vocabulary	31.47 (7.96)	32.50	7	47	-.603 (.304)	.326 (.599)	.151 (.001)	.968 (.101)
Text comprehension	11.02 (3.19)	11	3	16	-.350 (.304)	-.216 (.599)	.127 (.014)	.957 (.030)

Before the analysis, tests for normality were conducted. Given the sample size ( $n=62$ ) the indices of asymmetry and kurtosis were considered, from which it is deduced that the distribution of the data is normal. Parametric analysis of correlations between variables was conducted (Table 4).

**Table 4.**

Individual differences: correlations

Measure	1	2	3	4
Working Memory	---	.126	.117	.127
Speed Processing	.126	---	---	-.100
Vocabulary	.117	-.043	-.043	.277*
Text Comprehension	.127	-.100	.277*	---

\* $p < .05$

Correlation analysis detected a statistically significant direct correlation between the vocabulary variable and the comprehension of academic texts ( $r=.28$ ,  $p<.05$ ), with a median effect size ( $R^2=.08$ ). Both variables share a common 8% variance. No statistically significant correlations were detected between executive working memory functions and processing speed with academic text comprehension.

## CONCLUSION

In the present study, we examined the role of inhibition, goal setting, working memory, speed process and vocabulary in the comprehension of academic texts by making using of a reading experiment combined with an individual differences approach. It was expected to know the effect of executive functions on the comprehension of academic texts to determine whether the differences in reading comprehension in older students can be explained by executive functioning alone (Potocki et al. 2017).

The interaction effect between goal setting and inhibition on academic text comprehension detected in the experimental study is consistent with the perspective of executive functions as a construct formed by multiple processes that operate in an interrelated mode during the execution of novel or complex tasks (Anderson 2002; Friedman et al. 2016). According to the existing empirical evidence, the findings of the experimental study demonstrate that the execution complex tasks, in this case the reading of an academic text that is interrupted by distractors, is conducive to the deployment of multiple processes, such as interference control and the deployment of goal-directed reading organization/planning strategies: for interference control, through inhibitory control functions, such as inhibition of a prepotent response (not looking at the distractors) or resistance to distracting interference (suppressing the information contained in the distractors); and in the case of goal setting, through the recognition of relevance cues (provided in the instructions) for the consecution of a reading goal. Thus, having instructions before reading allows better results in the comprehension of an academic text when reading is interrupted by distractors, which could indicate that the reader controls and regulates his cognitive processes when the

situation requires it. That is, relevance instructions in the comprehension of an academic text could have an impact on the activation of readers' attentional control when reading (Jian 2018; León et al. 2019) is interrupted by distractors, because attention to relevant information during reading while ignoring a distractor implies a high cognitive demand (Rozek et al. 2012; Wilcockson et al. 2019).

One finding that requires further investigation is the effect of goal setting on comprehension of academic texts. We expected to find a main effect of instructions on comprehension in the two reading conditions (with/without distractor). However, instructions or specific guidance seem to have been especially helpful only when the task was more complex, such as in the presence of distractors. This result aligns with previous research developed with younger students, where the presence of specific instructions, aids, and guidance improves reading comprehension scores (Bohn-Gettler and McCrudden 2018; Cerdán and Marín 2019; Cerdán et al. 2019; McCrudden 2019). Experiments with a larger sample size could help define whether this interaction effect between instructions and distractors is replicated and consolidated in reading tasks from academic texts. On the other hand, in relation to the effect of the variable inhibition on the comprehension of academic texts, the differences detected were not significant, which is consistent with previous research in studies in which it indicates that not in all studies it is possible to prove the influence of inhibition on reading comprehension (Follmer 2018; Lu and others 2017). In turn, this result can be interpreted as a distinctive feature of executive functions: although they are dissociable their influence is determined by another or other executive processes, in this case, setting reading goals, which are triggered when the task is novel or complex (Anderson 2002; Diamond 2013).

The relationship between working memory and academic text comprehension was not as expected according to previous study (Bohn-Gettler and Kendeou 2014; Christopher and others 2012; Follmer 2018; Ober et al. 2019; Peng et al. 2018; Perfetti and Stafura 2014), which could be attributed, on the one hand, to the level of automation of reading skills in the sample, which impacts the efficiency in the use of working memory resources (Christopher et al. 2012). This result agrees with the findings reported by Guerra and Kronmüller (2019) who evaluated young adults in conditions

similar to those of this study and did not detect statistically significant correlations between working memory and reading comprehension. Another possible explanation for the previous result follows the line of findings reported by Van Dyke et al. (2014), who detected an influence of vocabulary on reading comprehension mediated by working memory. Thus, there could be an indirect relationship between this variable and comprehension that can be explained through access to retrieval cues determined by lexical knowledge. This would explain why no statistically significant correlation was detected between working memory and comprehension of academic texts, although vocabulary did correlate positively with comprehension in the sample analyzed.

The relationship between processing speed and comprehension of academic texts was also not as expected. This result partially coincides with the findings reported by Borella and his collaborators (2014, 2011) who concluded that variations in reading comprehension cannot be explained by differences in processing speed independently, but that its effect could be indirect through working memory. Studies aimed at analyzing text processing would allow detecting clearer relationships between this variable and information integration processes during reading based on the premise that the relationship between processing speed and comprehension is determined by decoding efficiency, the amount of text read, the integration of text and its meaning (Christopher et al. 2012). Further studies oriented to the study of text processing could confirm this assumption.

In relation to vocabulary, the results of this research are consistent with findings reported in previous research that have tested the impact of lexical knowledge on comprehension (Freed et al. 2017; Guerra and Kronmüller 2019; Perfetti 2007; Perfetti and Stafura 2014; Ribeiro et al. 2016; Van Dyke et al. 2014; Yildirim et al. 2011). Given that the comprehension tests of each text assess three dimensions of comprehension (textual, pragmatic and critical), in which local and global coherence processes are determinant (Riffo et al. 2013), this study provides evidence on the influence of vocabulary not only on the local coherence processes that facilitate inferences (Guerra and Kronmüller 2019), but also on the global coherence processes involved in the construction of the semantic representation of an academic text. Thus, it is possible to



propose that the relationship between vocabulary and reading comprehension is not only explained by the knowledge of the meaning of words, but also accounts for the role played by lexical knowledge in the functional architecture of language (Van Dyke et al. 2014), where the quality of lexical representations would allow to activate processes of retrieval and access to meaning that seem to be more efficient in readers a greater amplitude of general vocabulary in readers that have a greater amplitude of general vocabulary.

Finally, the results in relation to vocabulary are consistent with studies in which the influence of this variable on comprehension was compared according to different types of text (narrative, expository), where it was detected that vocabulary amplitude is related to a greater extent with the comprehension of expository scientific texts than with the comprehension of narrative texts (Follmer and Sperling, "A latent", "Interactions"; Yildirim et al. 2011). Therefore, from the findings of this study, it is possible to propose that the general lexical knowledge level of entering college students might be a relevant factor in understanding individual differences in academic text comprehension. However, further studies in the field of academic text comprehension are needed to test this hypothesis.

In summary, executive functions alone cannot explain the differences in comprehension performance detected in the sample tested. Together with inhibition and goal setting, lexical knowledge seems to play an important role in individual differences in the comprehension of academic texts in students beginning their university education. Considering that vocabulary is directly related to people's cultural opportunities and access to the written code, it is relevant to consider this component in future reading interventions in university students, given that the cultural capital of students entering university is diverse.

## LIMITATIONS

The main limitation of the research was the sample size. Nevertheless, the correlation detected between vocabulary and academic text comprehension constitutes an important

finding for the study of academic text comprehension that should be contrasted in future studies. At the same time, not having an additional measure to assess inhibition capacity did not allow us to determine the role of this executive function in the comprehension of academic texts independently of the instructions. To clarify the effect of instructions on the comprehension of academic texts, future studies should independently analyze instructions of general and specific relevance. Nevertheless, the statistical power of the experimental study enables us to affirm that instructions facilitate the comprehension of academic texts when reading is interrupted by distractors.

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