



Reading comprehension of scientific informative texts among schoolchildren

Comprensión de lectura de textos informativos de carácter científico

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Abstract

The purpose of this work was to determine the contribution of fluid intelligence and executive functions such as working memory and inhibitory control and verbal fluency, to the understanding of reading scientific informative texts among schoolchildren. Likewise, the contribution of syntactic consciousness was analysed, seen as a metalinguistic ability, to reading comprehension of this type of textual structure. A cross-sectional, exploratory-descriptive design of correlational scope was used. The sample included 175 Chilean schoolchildren of both genders, in their 4th and 5th year of primary education of two educational centres. Measures of fluid intelligence, working memory, inhibition, syntactic awareness and reading comprehension of expository texts were taken. The results show statistically significant, but weak, relationships between fluid intelligence, working memory, inhibition and reading comprehension of informative texts and moderately significant relationships between syntactic awareness and reading comprehension of this type of textual structure.

Resumen

El presente trabajo tuvo como propósito determinar la contribución de la inteligencia fluida y de funciones ejecutivas tales como la memoria de trabajo y el control inhibitorio y la fluidez verbal, a la comprensión de lectura de textos informativos de carácter científico en escolares. Asimismo, se analizó la contribución de la conciencia sintáctica, en tanto que habilidad metalingüística, a la comprensión de lectura de este tipo de estructura textual. Se utilizó un diseño transversal, exploratorio-descriptivo, de alcance correlacional. La muestra incluyó 175 escolares chilenos de ambos sexos, de 4° y 5° año de educación primaria de dos establecimientos educacionales. Se tomaron medidas de inteligencia fluida, memoria de trabajo, inhibición, conciencia sintáctica y comprensión de lectura de textos expositivos. Los resultados muestran relaciones estadísticamente significativas, pero débiles, entre inteligencia fluida, memoria de trabajo, inhibición y comprensión de lectura de textos informativos. Las relaciones entre conciencia sintáctica y comprensión de lectura de este tipo de textos, en cambio, son significativamente moderadas desde el punto de vista estadístico.

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Introduction

The specialised literature indicates that informative texts pose significant challenges to student understanding at different levels of education (Manzanal-Martínez, Jiménez-Taracido & Flores-Vidal, 2016). Some international measurements also show student limitations when understanding scientific texts (Organisation for Economic Cooperation and Development, OECD, 2012). In spite of this, research on reading comprehension of this type of texts and its underlying skills are not entirely conclusive.

Informative texts are an important resource for some learning processes, as they address scientific knowledge (De-Mier, Amado & Benítez, 2015; Goldman & Bisanz, 2002). In the school context, the school textbook or manual is the official means of scientific literacy used by the school and, therefore, it is the main means of access to the contents and learning expected in the curriculum. The didactic function of the texts included in the science textbook is triggered through rhetorical forms that allow the discursive reconstruction of facts from the natural world, so that they can be recognised, understood and accepted as real by students (Izquierdo, 2005). Therefore, the way of communicating such facts mainly responds to an explanatory purpose: describing certain phenomena, making their causes and effects known, analysing the factors or conditions involved, the questions they raise and the answers science has provided to such phenomena, *inter alia*. In other words, these texts inform or expose the reader to something about the real world, whose functioning, and even its existence, needs to be revealed. For this reason, they are identified as “expository” or “informative” texts, as they introduce something unknown that requires a mediator presenting it in a way that is understandable to the reader.

From the text-discourse perspective, in informative texts there is a strong presence of

the referential function of language, technical vocabulary and external textual clues to present information to the reader (photos, models or others); they use generic nominal structures (animals, ecology), abstract nouns and causal sentences, *inter alia* (Manghi, Arancibia, Illanes, Herrera & Zamora, 2014; Manzanal-Martínez et al., 2016). Their communicative purpose is expressed through conventional resources that operate as instructions to the reader so that they can understand the text. These resources mainly correspond to linguistic and rhetorical forms that in turn correspond to certain prototypical structures that organise the logical relationships between the concepts or ideas that the author wishes to convey. According to the classic classification proposed by Meyer (1985), they correspond to cause-effect chains, problem-solution, theory-demonstration, comparison-contrast, information-description or texts with classifications.

However, which general and/or specific skills contribute to reading comprehension of this type of texts?

Fluid intelligence, executive functions and their link to reading comprehension of scientific informative texts

From a cognitive perspective, several studies have shown the role of intelligence and executive functions in reading comprehension of narrative texts (Cuetos, González & De-Vega, 2015; Flores-Macías, Jiménez & García, 2015). However, the contribution of these same variables to reading comprehension of scientific information texts at intermediate levels of education has not received the same attention.

With regard to intelligence, Horn and Cattell's hierarchical model (1966) distinguishes two factors in its structure: fluid intelligence and crystallised intelligence. The first one is more dependent on the biological and neurological sphere (Kieng, 2017) and reflects the ability to solve new or unfamiliar problems. The second

one refers to the ability to solve tasks involving knowledge rooted in experience, education and culture (Ziegler, Danay, Heene, Apsendorpf & Bühner, 2012). Ningrum & Wibowo (2017) show a significant contribution of intelligence to reading comprehension in a group of 32 high-school students in Indonesia. In the same vein, Primor, Pierce & Katzir (2011) found that scores on the Raven's Progressive Matrices Test (2014) predicted comprehension of narrative and informational texts in Israeli fourth graders, with and without reading difficulties. On the contrary,, Corso, Cromley, Sperb & Salles (2016) found no direct link between fluid intelligence, measured with the same test, and reading comprehension in Brazilian fourth and sixth graders. It seems that studies on the link between fluid intelligence and reading comprehension are not entirely conclusive.

On its part, school learning seems to be a type of activity that requires executive functions for its proper development. The concept of executive functions lacks a unitary character (Tirapu-Ustárroz, García-Molina, Luna-Lario, Verdejo-García & Ríos-Lago, 2012; Tirapu-Ustárroz, Muñoz-Céspedes & Pelegrín-Valero, 2002). However, although there is a wide range of explanatory models, some aspects seem to be nuclear and are repeated in most of them. In describing executive functioning, Fuster (1989) determined that its main tasks were 1) maintaining an immediate provisional memory, 2) behaviour planning, and 3) suppressing any interference that constraints behaviour planning and execution. A series of research studies have shown the role of executive functions in school learning. Clair, Thompson & Ghercole (2006) show that the development of executive functions in the pre-school stage is a predictor of positive adaptation to school. More recent research suggests a consistent link between academic performance and executive functions in school children aged 6 to 12 years old (Fonseca, Rodriguez & Parra, 2016). More specifically, it has been noted that working

memory and inhibition are cognitive domains especially linked to a correct performance in reading comprehension.

Working memory corresponds to a process of temporary retention of information by the phonological loop and the visual and spatial agenda (Baddeley & Hitch, 1974; Baddeley, 2010). both systems present limitations in terms of capacity and time to retain information. Such limitations are usually addressed by operating the third component of working memory: the supervisory attentional system that seems to contribute to active retention, maintenance/ updating of information and coding processes, *inter alia* (Shallice, 1988; Tirapu-Ustárroz & Muñoz-Céspedes, 2005). A series of studies have addressed the link between working memory and reading comprehension. González, Otero & Castro (2016) found positive and significant correlations between verbal working memory and reading comprehension in 59 Cuban fifth graders of primary education. These remarks are consistent with those found by García-Madruga, López-Escribano, Elosúa & Gómez-Veiga (2013). Recently, De-la-Peña & Badell (2019) established a link between reading comprehension and working memory in Mexican female third graders. On the other hand, Torres-Rodríguez, Zuluaga & Varela-Cifuentes (2016) studied this link in 21 Colombian children with attention deficit hyperactivity disorder (ADHD) and 21 control third graders and fifth graders. They found that the group with ADHD performed worse in working memory and reading comprehension, as opposed to the control group. However, when measuring working memory with direct and inverse digit retention tasks, they did not find any differences in terms of performance between the group with ADHD and the control group. This case suggests that working memory tasks that correlate with reading comprehension should be different from simply retaining and repeating lists of numbers or names.

Inhibition is defined as a cognitive process of suppression of automatic behaviour in benefit of alternative behaviours (Diamond, 2013; Slachevsky, Perez, Silva, Orellana & Prenafeta, 2005). Some authors argue that it is activated as a suppression of distracting information that competes with that linked to the achievement of objectives (Cartoceti & Abusamra, 2012; Cartoceti, 2012). Inhibition would facilitate the selection of appropriate behaviours and information for the programming and execution of internally guided activity patterns. Insufficient inhibition of irrelevant information would generate a saturation of working memory, thus making processing difficult in reading comprehension tasks (Carocetti & Abusamra, 2012). In this regard, some studies show that English-speaking children aged 7 to 8 with decreased reading comprehension have difficulty inhibiting irrelevant information (Pimperton & Nation, 2010).

Syntax Awareness and Reading Comprehension of Informative Texts among schoolchildren

Syntactic awareness is a metalinguistic skill that allows explicit manipulation of the syntactic aspects of language. This process fosters conscious control over the application of the grammatical rules that are necessary to establish the link between the components of the sentence and to access its meaning (Andrés, Canet y García, 2010; Cuetos, 2013).

The link between syntactic awareness and reading comprehension has not been fully clarified. Research has been mainly based on understanding of narrative texts and its results are not conclusive (Mariángel & Jiménez, 2015). In this regard, the study conducted by Bowey & Patel (1988) on six-year-old Australian children reports a positive correlation between these skills. However, syntactic awareness did not prove to be a predictor of reading performance at that age. On their part, Arya, Hiebert & Pearson (2017) examined the contribution of lexical

complexity and syntactic complexity to reading comprehension of informative texts in English-speaking third graders. The study concluded that lexical complexity had a significant impact on the comprehension of two of the four topics under evaluation. The syntactic complexity of the texts, however, did not affect comprehension, regardless of the subject matter of the texts presented to the schoolchildren.

In this context, our study aims at contributing to clarify the link between syntactic awareness and cognitive variables such as fluid intelligence, working memory and inhibition with reading comprehension of scientific information texts in Spanish-speaking schoolchildren aged between 9 and 11.

Method

Design

An exploratory cross-sectional design was used, with a predictive correlational range in two age groups.

Participants

The purposeful, non-probabilistic sample included 175 schoolchildren of both genders (82 boys and 93 girls) from grade 4 and 5 of primary education in two state-subsidised educational establishments in the Biobío Region, Concepción, Chile. The mean age was 9.68 (SD = .52) in grade 4 and 10.54 (SD = 0.51) in grade 5. The distribution of the sample by grade and gender is shown in table 1.

Table 1
Distribution of the sample by year and gender

Year	F	M	Total
Grade 4	58	47	105
Grade 5	35	35	70
Total	93	82	175

Measures and Instruments

The following instruments were used to measure the variables under study:

Fluid intelligence: evaluated through the Raven' Colour Progressive Matrices Test (2014). This instrument is made of 36 problems presented in an equal number of incompletely coloured drawings, arranged in a booklet. At the bottom of each of them, there are six small drawings, of which only one is useful to correctly complete the incomplete drawing. The 36 sheets are distributed in three series of 12 drawings each, called series A, Ab and B. The problems are arranged in increasing complexity, A being the easiest and B the most difficult. The problems in the A, Ab and B series are a test of structured perception and relationship education. The functions that are mainly analysed are the following: size perception, perception of orientation in space in one direction and in two directions simultaneously, and apprehension of discrete figures especially related to a whole. With regard to the psychometric properties of the instrument, it is considered a highly reliable instrument ($\alpha = .82$).

Working memory: this skill was evaluated by applying a forward and backward digit Span task and a direct and inverse letter Span task from Reynolds & Bigler's Test of Memory and Learning (2001). Direct scores can be converted into scale (1-20) and percentile (1-99) scores, depending on age. The total reliability of the subtests was calculated using Cronbach's Alpha and with test - retest, being $\alpha=.96$ and $r=.80$ for the age of 10 and 11.

Inhibitory control: the skill was evaluated through Golden's Colour and Word (STROOP) (2010). This test provides a measure of the sensory interference that is generated when a routine activity, such as reading words, is in competition with a new activity such as naming the colour in which a word that names a differ-

ent colour is printed (e.g., the "red" word printed in green). It consists of three subtests: in the first one, the individual has to read a list of words that name three colours (red, blue, green) as quickly as possible, for 45 seconds; in the second one, the individual has to name colours (red, blue, green) as quickly as possible, for 45 seconds; in the third one, the individual has to name the colour in which a long series of words that name colours are printed as quickly as possible, for 45 seconds. An interference rate of 0 is deemed to be normal for direct scores of the three subtests; values above 0 indicate good interference control; values below 0 indicate a poor level. The reliability of the test with the test-retest method throughout different editions is $r = .88$, $.79$ and $.71$ for reading words, colours and word-colour, respectively (Golden, 2010).

Syntactic Awareness: evaluated through the Reading Process Evaluation Test (PROLEC - R), by Cuetos, Rodríguez, Ruano & Arribas (2010). This psycho-pedagogical range is aimed at first to sixth graders and can be applied individually. It explores four processes: letter identification, lexical processes, grammatical processes and semantic processes. Only the module of grammatical processes was used to evaluate syntactic awareness, the former including two sub-tests:

- Grammatical Structures Subtest (Subtest 5): The purpose of this activity is to test the readers' ability to perform syntactic processing of sentences with different grammatical structures. It consists of 16 items (plus one essay), each one consisting of four drawings and a sentence. The child has to read the sentence and identify the one that corresponds to the sentence among all four pictures. All sentences are reversible, i.e., the subject and object of the action can be exchanged. There are four different types of sentences and each one includes four stimuli: active, passive, focused object, and relative subordinate clauses.
- Punctuation Marks Subtest (Subtest 6): The purpose of this test is to check the reader's

knowledge and use of punctuation marks. To that end, the child is asked to read aloud a short story that includes the major punctuation marks (they have to read it noticing these signs). Eleven signs are punctuated corresponding to the reading intonation of four points, two commas, three interrogation marks and two exclamations marks. Correction is obtained in direct scores in the processes represented by the main indexes (Grammatical Structures and Score Signs) and those of secondary precision (Reading Accuracy, Pace and Ability). The range reliability index obtained with Cronbach's Alpha coefficient amounts to 0.79.

Reading comprehension of informative texts: this variable was studied through the Reading Comprehension and Text Production Test (CL-PT), by Medina & Gajardo (2009). It evaluates three areas: reading comprehension, text production and language skills. Only the axis that explores reading comprehension of scientific information texts was applied for research purposes. For grade 4 of primary education, this area includes an informative scientific text of a continuous nature on the elephant and two discontinuous texts: a geographical map of the region and a map of the country including information on environmental temperature and the index of solar radiation. For grade 5, it includes a text of scientific information on the deterioration of biodiversity and a discontinuous text corresponding to a graph showing the proportion of species of vertebrates and plants, with populations in danger of extinction. The reliability index reported as a test-retest correlation coefficient ranges from a minimum of .57 to a maximum of .76, with a value of $p < .001$. On the other hand, the reported construct validity for the test ranges from a minimum of .40 to a maximum of .59, with a value of $p < .001$ (Medina & Gajardo, 2009). The correction allows for direct and percentile scores by grade.

Procedure

Informed consent was obtained from two educational institutions in the Biobío Region, Chile. The ethical standards contained in the Declaration of Helsinki regarding human research were respected throughout the research process. In first place, the Raven's Coloured Progressive Matrices Test (2014) was applied in small groups. The cognitive tests were then applied individually, and the reading comprehension measurement was implemented in a small group. All evaluations were conducted in facilities provided by the schools.

Data Analysis Techniques

The data analysis was carried out using the SPSS Version 24 software. In first place, the normality of the variables was verified using the Kolmogoroff-Smirnov Test. The correlation between the independent variables and the reading comprehension of scientific informative texts was established through the Pearson Correlation Coefficient r . Based on these results, we propose a multiple linear regression model to conduct the predictive analysis.

Results

In first place, the descriptive results of all the variables under study are reported. The results are shown in table 2.

There is a positive but weak correlation between fluid intelligence and executive functions and reading comprehension of scientific informative texts among fifth graders. On the other hand, inhibition and reading comprehension weakly correlate among fifth graders and in the total sample. With regard to working memory (reverse digit retention), the correlation is weakly positive in the total sample, but not in the analysis by grade. On the other hand, the results showed a positive and statistically significant link between syntactic awareness,

especially regarding the use of punctuation marks, and the school levels participating in the study. The results of the correlation study are shown in Table 3.

Finally, the linear regression model shows that, in grade 4, the working memory of direct letters and the syntactic awareness of punctuation marks explain 15% of the variance in reading comprehension of scientific informative

Tabla 2
Descriptives by year

Variables	Grade 4		Grade 5		Statistician	p
	M	R	M	R		
AGE	9.68	0.52	10.54	0.51	9507	<0.0001
CS. Grammatical Structures	13.41	1.63	13.34	1.79	6099	0.8499
CS. Punctuation Marks	6.92	2.16	6.81	2.42	6106	0.8681
SP-PACE	50.89	12.45	45.14	9.85	5099	0.0012
TOTAL SCORE PUNCTUATION MARKS	14.32	5.14	15.59	6.26	-1.47	0.1425
RAVEN.PD	40.4	4.52	40.24	4.87	0.22	0.8272
RAVEN.Perc	92.21	12.12	74.29	19.3	3927	<0.0001
MT.PD.DD	36.7	19.76	33.84	13.52	6100	0.8549
MT.PD.LD	26.72	12.86	26.43	11.32	6204	0.8933
MT.PD.DI	15.19	7.01	17.23	8.06	6800	0.0508
MT.PD.LI	13.19	5.92	14.27	4.59	6841	0.0377
STROOP.INT*	-0.48	4.74	0.24	6.27	-0.82	0.4112
Proportion.Text.Exp	13.36	3.94	28.54	6.67	-17.16	<0.0001

*STROOP. Interference

Table 3
Correlations by grade

Variables	Grade 4		Grade 5	
	r	p	r	p
Proportion CL. Expository Text				
Age	-.125	0.203	-.010	0.936
CS. Grammatical Structures. PD	-.016	0.873	.169	0.163
CS. Punctuation Marks. PD	.175	0.075	.268*	0.025
CS_PUNCT.MARKS Total %	.287**	0.003	.421**	0.000
Gf Score	.069	0.482	.245*	0.041
Gf Percentile	.061	0.538	.186	0.123
MT. PD. Direct Digits	-.115	0.242	.015	0.901
MT. PD. Direct Letters	-.113	0.251	.014	0.907
MT. PD. Reverse Digits	.046	0.641	.177	0.142
MT .PD. Reverse Letters	.034	0.731	.230	0.055
STROOP. INT. INH.	.036	0.716	.277*	0.020

Note: Gf= Fluid Intelligence; MT=working memory; INT.INH= Interference.Inhibition.

* The correlation is significant at a 0.05 level (bilateral).

** The correlation is significant at a 0.01 level (bilateral).

Table 4
 Model Summary for Grade 4

	Standardised coefficients			t	Next
	C	SE	β		
(Constant)	11.222	1.117		10.050	.000
TOTAL SCORE PUNCTUATION MARKS	.316	.077	.413	4.086	.000
MT.PD.LD	-.089	.031	-.292	-2.887	.005

R²=.152

texts. On the other hand, in grade 5, inhibition and syntactic awareness of punctuation marks are the variables that, as a whole, explain 28.3% of the variance in reading comprehension of this type of texts. In both grades, syntactic awareness proved to be the variable that best predicts reading comprehension of scientific informative texts referred to the use of punctuation marks modulated by reading pace. Tables 4 and 5 show these results, respectively.

Discussion

The purpose of this paper was to clarify the contribution of general skills, fluid intelligence and executive functions to reading comprehension of scientific informative texts among fourth and fifth graders. On the other hand, it was intended to analyse the contribution of a specific skill, such as syntactic awareness, to the reading comprehension of this type of text.

With regard to the role of fluid intelligence stated above, research is not entirely conclusive. In the same vein, this study could establish a statistically significant -but weak- link between fluid intelligence and reading comprehension of scientific information texts among fifth graders only. Therefore, this variable did not prove to be an important predictor of reading comprehension of scientific informative texts at the school levels under study. It seems that reading comprehension of these texts requires skills that are more linked to crystallised intelligence, related to the ability to solve tasks in which knowledge that is rooted in specific content taught by the school intervenes, rather than the capacity to solve new problems, inherent to fluid intelligence. In other words, previous knowledge of students could be a better predictor of the comprehension of this kind of texts, which can be supported by a series of studies that show the importance of this factor for the comprehension and learning from what

Table 5
 Model Summary for Grade 5

	Non-standardised coefficients		Standardised coefficients	t	Next
	C	SE	β		
(Constant)	20.874	1.862		11.208	.000
TOTAL SCORE PUNCTUATION MARKS	.486	.111	.457	4.387	.000
STROOP.INT	.347	.111	.327	3.139	.003

R²=.283

has been read (Cano, García, Justicia & García-Berbén, 2014; Tarchi, 2010).

With regard to the executive functions, the role of working memory as a predictor of variance in reading comprehension of scientific information texts was negligible in this study. The role of working memory in reading comprehension has been widely discussed when digit retention is used as a measurement procedure. It is well known that working memory is not a unitary construct (Baddeley, 2000; Funahashi, 2017; Miyake, 1999). Therefore, digit Span tasks are more linked to a specific subprocess within working memory than to working memory as a whole. Indeed, the activities of digit repetition in direct order seem to be more linked to the retention capacity of the phonological loop, and to the tasks of executive control to a lesser extent. This situation may explain the lack of correlation between Span tasks and reading comprehension in both grades. In a nutshell, our results allow us to conclude that reading comprehension of scientific informative texts does not depend on the amount of information retained but on what the individual does mentally with the information they retain. In this regard, Barreyro, Injoque-Ricle, Álvarez-Drexler, Formoso & Burinque (2017) suggest that, in order to understand expository texts, the facilitating effect of working memory would occur in readers with previous knowledge of the specific domain of the text read. In any case, it would be interesting to compare these results to those of students with reading difficulties, as proposed by some authors (Miranda-Casas, Fernández, Robledo & García-Castellar, 2010).

On the other hand, the results of the correlation analysis between STROOP inhibition tasks and reading comprehension of scientific informative texts in grade 5 seem more aligned with previous research experiences (Carocetti & Abusamra, 2012; Pimperton & Nation, 2010). Indeed, the low to moderate correlation found in this study at that school level suggests that

control for interfering stimuli may be a valuable indicator of reading comprehension of this type of texts. However, it might be wondered whether the results refer to the subject's ability to inhibit external distracting stimuli or to internal stimuli related to concepts, beliefs and/or thoughts. Information contained in scientific expository texts is often counter-intuitive (e.g. "the Earth revolves around the Sun"; "humans and snails share a common ancestor") and it is precisely these ideas that should probably be suppressed or moderated by inhibitory control to make it possible to process the information contained in the text. Clearly, more research is needed at this point to argue that inhibition does not only control access to information in processing centres, but it rather acts as a filter against experience-based information in favour of evidence-based information. Therefore, reading expository or informative texts of a scientific nature would imply inhibiting experiential knowledge to allow the processing of logical information not related to direct experience. In the same vein, several studies suggest that scientific thinking is a mechanism for slowing down automatic response (Roland, 2016).

We conclude that reading comprehension, as stated by several authors (Gernsbacher & Kaschak, 2013; Kintsch, 1998), is a highly complex process that seems to increase when it refers to reading texts with a function and layout different to the prototypical form of narration, which is much closer to the layout form of everyday experiences than the informative texts studied in this study.

Finally, syntactic awareness turned out to be the variable that best predicted reading comprehension of scientific informative texts at the school levels under study. This link, specifically referred to the awareness of punctuation marks, could be explained by the fact that punctuation marks somehow allow to delimit the sentences and paragraphs that give meaning to informative texts of a logical-scientific nature, which

would facilitate, in turn, a better understanding of the meaning of the text.

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