

## Cognitive and executive processes associated with children's writing

### Procesos cognitivos y ejecutivos asociados a la expresión escrita infantil

Cecilia B. Moreno<sup>1,a</sup> , Celina Korzeniowski<sup>2,3</sup> , Adriana Espósito<sup>3</sup> 

<sup>1</sup> Pontificia Universidad Católica Argentina, Mendoza, Argentina

<sup>2</sup> Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina

<sup>3</sup> Universidad del Aconcagua, Mendoza, Argentina

✉ <sup>a</sup> Correspondent author: [cecilia\\_moreno@uca.edu.ar](mailto:cecilia_moreno@uca.edu.ar)

Received: 01/10/2021; Accepted: 16/03/2022

### Abstract

Learning to write is key to successfully going through elementary education. Considerable progress in children's writing is documented in the intermediate school grades, due to lexical and cognitive development. In line with this postulate, the goal of the study was to analyse the predictive value of attention, perception, planning, working memory and long-term memory in written expression tasks in Argentine schoolchildren. One hundred and sixty-eight boys and girls participated, between 8 and 11 years of age, who were in 3rd, 4th and 5th grade of Elementary Education. A regression analysis revealed that visuospatial perception, working memory, long-term memory, and planning may predict writing performance in children. Working memory denoted a high predictive value, along with long-term memory and visuospatial perception. The findings provide evidence about the involvement of cognitive and executive processes in written expression tasks in Spanish-speaking schoolchildren. Identifying cognitive predictors of writing skills makes it possible to design more comprehensive teaching programs that jointly contemplate training in specific writing skills and strengthening the cognitive resources of learners.

**Keywords:** Writing ability; writing skills; executive function; cognitive processes; Primary Education.



## Resumen

Aprender a escribir es clave para transitar con éxito la Educación Primaria. En los grados escolares intermedios se registra un progreso significativo en la escritura infantil, debido al desarrollo lexical y cognitivo. En línea con este postulado, el objetivo del estudio fue analizar el valor predictivo de la atención, percepción, planificación, memoria de trabajo y memoria a largo plazo en tareas de expresión escrita en escolares argentinos. Participaron 168 niños y niñas, entre 8 y 11 años de edad, que cursaban 3er, 4º y 5º grado de Educación Primaria. A partir de un análisis de regresión, se observó que la percepción visoespacial, la memoria de trabajo, la memoria a largo plazo y la planificación predijeron el desempeño en expresión escrita en los niños. La memoria de trabajo denotó un alto valor predictivo, junto con la memoria a largo plazo y la percepción visoespacial. Los hallazgos aportan evidencia sobre la involucración de procesos cognitivos y ejecutivos en tareas de expresión escrita en escolares hispanohablantes. Identificar predictores cognitivos de las habilidades de escritura permite diagramar programas de enseñanza más abarcativos, que contemplen conjuntamente el entrenamiento de las habilidades escritoras específicas y el fortalecimiento de los recursos cognitivos de los aprendices.

**Palabras clave:** Capacidad de escritura; habilidades de escritura; función ejecutiva; procesos cognitivos; Educación Primaria.

## INTRODUCTION

Writing is a distinctive human activity and has geared social and scientific progress. Writing is a central aspect of formal education and is critical to success in school and everyday life.

In the last years, in Latin America, there has been a decline in writing skills, and more particularly, in terms of text production. According to reports, about 50% of elementary schoolchildren perform poorly when constructing meaning in a written text ([Ministerio de Educación de la Nación Argentina, 2018](#)), and about 30% lack skills in using linguistic conventions ([Ministerio de Educación de la Nación Argentina, 2017](#)).

Similar percentages have been reported in other Latin American countries. Elementary schoolchildren are below the world average in knowledge of the spelling code, in textualization, planning and text revision ([Ministerio de Educación de la Nación Argentina, 2018](#); [United Nations Educational, Scientific and Cultural Organization \[UNESCO\], 2020](#)).

For this reason, research aimed at exploring writing skills in Latin American schoolchildren is needed. Studies are still insufficient in comparison to the number of existing studies on reading. This is due to the methodological complexity involved in studying writing procedures ([Abusamra et al., 2020](#)), which derives from the cognitive functions involved in the writing process.

### Writing as cognitive processing

In cognitive models, writing is conceptualized as an activity involving planning, transcription, and revision ([Flower & Hayes, 1981](#)). Planning implies generating previous schemes, establishing the goals of the text and its organization. Transcription involves translating those ideas into written text. In the transcription phase, motor, lexical, syntactic, and semantic aspects are involved. Revision implies rereading and rewriting what is written, identifying and correcting errors to adjust the text ([Scardamalia & Bereiter, 1992](#)).

Transcription has been widely studied ([Abusamra et al, 2020](#); [Cordeiro, et al., 2019](#); [Miranda, 2019](#)) among those processes. Some studies have focused on spelling, handwriting, and on phoneme-grapheme connections ([Defior-Citoler et al., 2000](#)). Other studies have analysed the genesis of the text and more complex discursive structures ([Salas and Silvente, 2019](#); [Drijbooms et al., 2017](#)). They all provide evidence of handwriting and spelling, as skills that are later automated, enabling more complex writing skills.

Transcription skills are acquired in the early school grades. A study by [Cordeiro et al. \(2019\)](#) conducted in second grade children showed that transcription skills predict text quality. Another study ([Alves & Limpo, 2015](#)) found that transcription continues to be important throughout the learning process, conditioning written production.

Writing proficiency can be improved in higher school grades ([Fitzgerald & Shanahan, 2000](#)). If transcription is automated, cognitive resources are freed, enabling other more complex processes such as planning and revision to improve text production and quality ([Hooper et al., 2002](#)).

## Visuospatial perception

The ability to discriminate visual stimuli is essential in transcription and in the motor process of handwriting. It is a low-order process, due to its degree of automation, but it is important because learning to write requires visual and auditory perceptual maturity (Bravo-Cóppola, 2004).

Studies have revealed that the written trace, that is, the visual permanence of the text already written, reduces the demand on high-level cognitive resources because it acts as an external auxiliary memory and facilitates revision process, in the most competent writers (Olive & Passerault, 2012). In beginner writers, error detection relies on verbal processing, while proficient writers use visual search to identify morphological coherence in their texts (Chenoweth & Hayes, 2003).

## Attention

Attention is a complex multimodal process (Posner, et al., 2006). Its function is to direct cognitive effort, operating as a filter that selects the most pertinent information (Portellano Pérez, 2005). In addition, it is an indicator of performance in tasks that require a high level of cognitive control (Monteoliva, et al., 2017). In writing, it plays a central role in allowing the selection of relevant stimuli, inhibiting distractors, and sustaining cognitive effort.

## Long-term memory

Text production involves retrieving knowledge stored in long-term memory, such as specific information about the topic to be written, vocabulary, and lexical, syntactic, and grammatical structures (Hayes, 1996). Retrieving of this knowledge will be relevant in the course of thought and in expressive fluency and will allow the organization of words and phrases, integrating their semantic components to produce a coherent and articulated text (Abusamra et al, 2020; Mather & Woodcock, 2005).

## Executive functions

Writing a text is a problem-solving activity that calls upon higher order cognitive resources, such as executive functions (EF), in order to plan, organize ideas, correct errors and monitor the process (Drijbooms et al., 2015).

EF are essential processes to organize and self-regulate thought, behaviour, and emotions (Tirapu-Ustarróz et al., 2005). They maintain a hierarchical relationship with the rest of cognitive processes, regulating them to solve novel and complex situations (Korzeniowski et al., 2016).

There is a consensus in the scientific literature that identifies three essential EFs: inhibitory control, working memory and cognitive flexibility, on which other more complex ones such as planning, organization and metacognition are built (Miyake et al., 2001). Inhibitory control allows suppressing inappropriate behaviour and resisting the interference of distracting stimuli. Working memory keeps information online and operates on it. Cognitive flexibility allows one to change the perspective on a task and adjust responses to new requirements (Cordeiro et al., 2019; Introzzi et al., 2015; Korzeniowski et al., 2020). Among the complex EFs, planning makes it possible to identify a goal, organise the

sequence of steps to achieve it, anticipate consequences and review the mental map to direct action (Díaz et al., 2012).

Various studies have reported that EF are central to regulating writing. A study of 3<sup>rd</sup> and 4<sup>th</sup> grade children documented that inhibitory control, cognitive flexibility, and working memory predicted performance on storytelling tasks (Hooper et al., 2002). Another study focused on the contribution of inhibitory control and planning in note-taking tasks (Altemeier et al., 2006).

Working memory is key to writing a text. Research studies provide substantial evidence on its implication in the production of narratives in childhood (Berninger & Win, 2006; Marinkovich, 2002).

During writing, working memory manipulates and keeps linguistic symbols online. The phonological loop admits and retains verbal information for short periods of time and performs a review that allows representations to be preserved. While the articulatory review takes place, allowing the execution of verbal tasks, the phonological representation in long-term memory reconstructs words and phonological traces that have declined (Bohari-Lasaquero et al., 2017).

In this sense, children improve speech production as working memory becomes more efficient (García-Madruga et al., 2012). Likewise, children who are more competent in working memory achieve better performance in the spelling and pragmatic components of the text (Moreno, 2016).

Despite this evidence, there is still not enough knowledge about the relationship and effects of EF on writing skills in Argentine children.

In short, multiple cognitive processes shape the writing process and contribute to it in specific ways. These findings allow researchers to identify cognitive predictors of writing to be considered as new variables in the design of writing teaching programs.

Elementary education is crucial when it comes to learning to write. In the intermediate school years, great progress can be observed in the writing skills of children, who begin to automate transcription and develop planning and revision skills. Gains in cognitive development make these advances possible, and thus the middle grades are an optimal time to study the interrelationships of cognitive functions and writing tasks.

In line with this postulate, the goals of this study were: 1) to evaluate written expression in children from 3<sup>rd</sup> to 5<sup>th</sup> grade of elementary education, through sentence production and writing fluency tasks; 2) to describe the cognitive performance of children in attention, visuospatial perception, working memory, planning and long-term memory; and 3) to study the predictive value of children attentional efficacy, visuospatial perception, long-term memory, planning and working memory on their written expression skills.

Based on the body of research reviewed, the proposed hypothesis postulates that children's ability to produce written texts is linked to cognitive and executive processing.

## METHOD

### Participants

Participants were 168 children (boys = 84 and girls = 84) between 8 and 11 years of age ( $M = 9.65$ ,  $SD = .90$ ) from two elementary schools in Mendoza. The schools are urban,

and their population belongs to a medium and medium-low socioeconomic level (Dirección General de Escuelas, [DGE], 2021).

The sample was made up by three 3rd grade courses (n = 56), three 4th grade courses (n = 59), and three 5th grade courses (n = 53).

Participants who met the conditions of age, schooling and absence of specific language, attention or other cognitive disorders were selected. All the participants were Argentine Spanish speakers.

The curricular design for writing instruction addresses different aspects in each grade (DGE, 2019). The goal for third grade is the writing of words without omitting any letters and incorporating conventional spelling. Writing texts using planning strategies and progressive development of revision is expected. In fourth grade, cohesion, narrative components, and the incorporation of other text types are emphasized. In fifth grade, the focus is on consolidating coherence, cohesion, the semantic classification of words and the syntactic structure of sentences.

## Instruments

### Writing measures

#### Woodcock-Muñoz Battery III sub-tests

- a) Writing Samples Test (WS): this test evaluates the ability to write sentences in response to different demands. It consists of 30 items of increasing difficulty, containing stimuli (e. g., images, a set of words or an incomplete paragraph) from which one or more sentences must be written. The starting point depends on the student's grade level. If they are adults, the last items are completed. A score of 2, 1 or 0 points is awarded, according to the criteria for each item, and the total possible score is 60 points. Some spelling errors (e. g., accents or capital letters) are not penalized, but the omission of letters or other spelling errors (e. g., g/j, ll/y) are. In the items of intermediate complexity, the syntactic structure (e. g., presence of verb and subject and adaptation to the stimulus) are considered. In the more difficult items, criteria of coherence, cohesion and quality of the text are considered (Muñoz-Sandoval, et al., 2005).
- b) Writing Fluency Test (WF): it assesses the ability to write sentences quickly. It contains 40 items, arranged in increasing order of complexity. Each item shows an image and a set of three words from which a sentence must be written that is related to the image and contains the three words. There is a period of 7 minutes to complete the largest number of items. The rating is done by awarding 0 or 1 point. The answer is considered correct when the sentences are complete, clear, and coherent. Spelling errors, such as the absence of accents or omission of capital letters, are not penalized, while omissions or substitution of letters and the absence of any of the words of the stimulus are (Muñoz-Sandoval et al., 2005).

The assessment of these writing tests was carried out by members of the research team with training in writing models and experience in applying instruments that evaluate children's writing skills.

Additionally, both writing tests make it possible to form a cluster for the measurement of competence in Written Expression (WE) in terms of production fluency and writing quality.

## Measurement of cognitive and executive processes

*Magellan Scale of Visual Attention (EMAV)*: this test evaluates focused and sustained attention by assessing attentional efficacy. It is a cross-out test in which a visual search must be carried out according to a model stimulus (García-Pérez and Magaz-Lagos, 2000). It presents two versions: EMAV-1 for 6- to 9-year-olds, and EMAV-2 for 10-year-olds and older. This instrument has been standardized for Argentine schoolchildren (Carrada & Ison, 2013), with satisfactory internal consistency ( $\rho = 0.89$ ,  $n = 5779$ ) and adequate convergence and discrimination validity ( $r = .80$ ,  $p < .01$ ).

*Porteus Labyrinth Test (PLT)*: it evaluates planning skills (Marino et al., 2001) in subjects from 3 to 80 years of age. It consists of 10 mazes of increasing difficulty. The path from the entrance to the exit of the maze must be traced with a pencil, without previous rehearsal with the pencil or the hand, and without lifting the pencil. The evaluation according to the Porteus Quality Index (PQI) designed by Marino and colleagues (2001) offers a measure of planning skill. The PQI includes hits and misses, awarding one point for each maze completed. The final score ranges from 0 to 10 points. The internal consistency of the test for Argentine schoolchildren (Korzeniowski, 2015) obtained a moderately high index ( $\alpha = 0.80$ ).

*Rey-Osterrieth Complex Figure Test (ROCF)*: this test assesses visuoperceptual organization, that is, visuospatial and visuomotor skills, in a graphic execution task. The test has a copy phase and a memory phase. The stimulus, which is copied and then reproduced from memory, is a geometric drawing made up of 18 constituent elements. It has specific characteristics, such as the absence of a manifest meaning, low graphic complexity, and a sufficiently complex structure to require an analytical and organizing activity. The quality, precision and localization of the copy are valued (Smith and Zahka, 2006). In our research, the criteria provided by a study carried out on Argentine children (Espósito & Ison, 2011) were used. It has three scoring criteria: a) precision that can be correct, deformed, incomplete or absent; b) location, according to the location with respect to the model; c) number of elements according to the number of units made.

*Auditory Working Memory Test, Battery III Woodcock – Muñoz*: It measures the phonological loop of working memory, as indicated by the recoding of acoustic stimuli held in immediate awareness. A series of digits mixed with words is heard and that information needs to be divided, reordered, and repeated in new sequences. The rating ranges from 0 to 42 points. The reliability is 0.80 for subjects aged 5 to 19 and 0.84 for adult subjects (Muñoz-Sandoval et al., 2005).

*Recovery Fluidity Test, Battery III Woodcock – Muñoz*: it evaluates recovery of accumulated knowledge and ideational fluency. It is a measure of long-term memory. It requires the retrieval and oral production of examples of a semantic category in one minute. In each category, subjects are requested to name foods, animals, and people. The score for each block ranges from 0 to 60 points and the total score ranges from 0 to 180 points. Test reliability is 0.83 for 5- to 19-year-olds and 0.91 for adults (Muñoz-Sandoval et al., 2005).

## Procedure

The procedure was developed following the ethical standards for psychological studies with children (American Psychological Association, 2017). To include the participants, the informed consent of their parents or guardians was required, and the children's agreement to participate was requested.

The tests were administered between August and October (spring), during school hours. Those tests that admitted a group application were carried out in the classroom with the help of a teacher. The individual application tests were administered in a separate room under adequate conditions for these tasks, which require greater execution control.

## Data Analysis

The data was analysed with the SPSS-IBM software, version 25. The normality criteria of the variables were analysed to establish their distribution parameters and then descriptive analyses were performed. Univariate analyses of variance were performed to assess the variability of writing performance in each school grade. A study of correlations between the cognitive and writing variables was carried out, using the Pearson and Spearman coefficients, according to the normality of the variables.

Finally, a hierarchical stepwise linear regression study was performed to explore the predictive value of cognitive and executive variables over writing variables.

## RESULTS

### Descriptive study

The Shapiro-Wilk test revealed that most of the variables presented a normal distribution. Table 1 reports the descriptive measures of writing and cognitive variables.

**Table 1. Descriptive Statistics and Normality for Writing Variables and Cognitive Variables**

<i>n</i> =168	Mean	Median	DS	Min.	Max.	Asymmetry	Kurtosis	Shapiro-Wilk	W	SW	<i>p</i>
Writing											
WS	19.14	19.14	5.69	2.00	33.50	-0.14	0.13	0.99		0.827	
WF	9.63	10.0	5.24	0.00	25.00	-0.00	-0.57	0.97		0.009	
WE	0.00	0.00	0.81	-2.40	2.13	-0.06	0.05	0.99		0.971	
Cognitive											
Attention	0.40	0.40	0.17	-0.01	0.87	0.07	0.55	0.97		0.008	
VP	48.10	48.81	10.22	20.5	72.0	-0.28	-0.41	0.98		0.115	
Planning	6.16	6.50	1.79	1.50	9.00	-0.52	-0.44	0.96		<.001	
WM	16.74	17.00	5.35	2.00	29.00	-0.27	-0.09	0.98		0.077	
LTM	43.17	42.00	12.03	10.00	81.00	0.39	0.64	0.98		0.048	

Note: WS: Writing Sample, WF: Writing Fluency, WE: Written Expression; VP: Visuoperception; WM: Working Memory; LTM: Long-Term Memory



Children's writing performance was explored. The raw scores of Writing Samples and Writing Fluency are presented. Standardized scores of Writing Samples and Writing Fluency were used to form the Written Expression cluster. This cluster is suitable for exploring writing competence because it takes into account structured writing ability and ideational fluency (Wendling et al., 2007). As there were no standardization norms for the instruments, intra-sample distribution was used, identifying children with low and high performance.

Table 2 presents the 25th, 50th and 75th percentiles of each writing test by school grade. It is observed that the values vary as the children advance in schooling, which shows the effect of schooling on writing competence.

**Table 2. Writing Variables and Cognitive Variables according to school grade: descriptive statistics and percentiles.**

	Tirth Grade (n=56)				Fourth Grade (n=59)				Fifth Grade (n=53)			
	M(DS)	Percentiles			M(DS)	Percentiles			M(DS)	Percentiles		
		25	50	75		25	50	75		25	50	75
Writing												
WS	19.78(5.44)	16.75	20.00	22.50	17.87 (5.46)	14.00	17.00	21.00	19.88 (6.03)	16.00	19.50	24.00
WF	7.05 (4.86)	3.25	6.00	11.00	10.20 (4.84)	6.00	11.00	14.00	11.70 (5.01)	8.50	12.00	15.00
WE	-0.18 (0.81)	-0.81	-0.16	0.38	-0.04 (0.77)	-0.38	-0.10	0.38	0.25(0.82)	-0.45	0.29	1.00
Cognitive												
Attention	0.41(0.19)	0.30	0.40	0.55	0.44(0.18)	0.32	0.42	0.55	0.35 (0.13)	0.27	0.34	0.42
Planning	5.44(1.87)	3.81	6.00	7.00	6.56(1.59)	5.50	6.75	7.75	6.45 (1.71)	5.25	6.75	7.87
VP	45.64 (9.65)	40.12	46.00	50.87	47.07 (10.48)	39.00	49.00	55.50	51.83 (9.71)	44.50	54.00	59.00
MT	15.29 (4.74)	13.00	16.00	19.00	17.50(5.62)	13.00	19.00	21.00	17.41 (5.42)	14.50	18.00	21.00
MLP	38.93 (12.11)	30.00	37.50	44.54	44.00 (11.00)	37.00	44.00	50.00	46.72 (11.91)	39.00	46.00	56.00

**Note:** WS: Writing Sample, WF: Writing Fluency, WE: Written Expression; VP: Visuoperception; WM: Working Memory; LTM: Long-Term Memory

The descriptive study was completed exploring the variation of writing performance by school grade. The ANOVA test indicated that writing fluency increased with progress in the school trajectory ( $F = 12.86$ ,  $p < .001$ ). Post-hoc comparisons indicated that 5th graders had higher writing fluency than their 4th and 3rd grade counterparts, and 4th graders outperformed 3rd graders. Likewise, it was observed that performance in written expression ( $F = 4.39$ ,  $p = .014$ ) was higher in 5th graders than in 3rd graders. Finally, no differences were observed in sentence writing ( $F = 2.30$ ,  $p = .103$ ) in relation to school grade.

These results reveal that participants' written expression and fluency in syntactic and semantic access improved in the upper grades.

In order to address the second goal of the study, the cognitive performance of students from 3rd to 5th grade was described and compared (table 1). Due to the lack of cognitive test standardization norms, percentiles were also calculated, identifying children with low, medium, and high performance. Table 2 shows that the values vary depending on the school grade, which shows the gains in the cognitive development of the students.

To weigh possible age differences in cognitive development, a series of ANOVAs were conducted. The results indicated that planning skills ( $F = 6.54$ ,  $p = .002$ ), attentional efficacy ( $F = 5.00$ ,  $p = .008$ ), visuospatial perception ( $F = 6.02$ ,  $p = .003$ ), working memory ( $F = 3.46$ ,  $p = .035$ ) and long-term memory ( $F = 5.91$ ,  $p = .004$ ) fluctuated depending on the school trajectory. Post-hoc analyses indicated that 5th graders showed the best cognitive performance, followed by 4th and 3rd graders. These results show that children increase in their cognitive abilities as they move on along their educational trajectory.

## Correlation study

The third goal aimed at analysing whether cognitive variables may account for performance in written expression. In order to do this, an associative test was performed.

The results (Table 3) indicated that written expression correlated positively with working memory ( $r = .267$ ,  $p < .001$ ), long-term memory ( $r = .294$ ,  $p < .001$ ), visuospatial perception ( $r = .293$ ,  $p < .001$ ) and planning ( $\rho = .235$ ,  $p < .01$ ). No correlation was observed with attentional efficacy ( $\rho = .80$ ,  $p = .32$ ).

Additionally, writing fluency and sentence writing were associated with cognitive functions. Sentence writing was associated with working memory ( $r = .160$ ,  $p < .05$ ) and long-term memory ( $r = .164$ ,  $p < .05$ ). Writing fluency was associated with working memory ( $r = .267$ ,  $p < .01$ ), long-term memory ( $r = .303$ ,  $p < .01$ ), visuospatial perception ( $r = .325$ ,  $p < .01$ ) and planning ( $\rho = .241$ ,  $p < .01$ ).

These results indicate that working memory, long-term information retrieval, planning, and visuospatial perception are significantly related to fluency and accuracy in writing sentences. Although the magnitude of these correlations was moderate, it allowed the explanatory models to be outlined.

**Table 3. Correlations between written expression, cognitive functions, and executive functions**

	1	2	3	4	5	6	7	8
1. WE	1							
2. WS	.810**	1						
3. WF <sup>a</sup>	.819**	.375**	1					
4. WT	.267***	.160*	.267**	1				
5. LTM	.294***	.164*	.303**	.345***	1			
6. VP	.293***	.110	.325**	.153	.127**	1		
7. Attention <sup>a</sup>	.080	.029	.045	.036	.020	.063	1	
8. Planning <sup>a</sup>	.235**	.113	.241**	.154*	.164*	.203**	.153*	1

**Note:** WS: Writing Sample, WF: Writing Fluency, WE: Written Expression; VP: Visuoperception; WM: Working Memory; LTM: Long-Term Memory. <sup>a</sup> Spearman Test; \* $p < .05$ ; \*\* $p < .01$ ; \*\*\* $p < .001$

## Regression Analysis

In order to carry out a predictive analysis, a multiple linear regression model was built using the hierarchical stepwise method. The Written Expression cluster score was taken as the dependent variable. The predictor variables were working memory, long-term

memory, planning and visuospatial perception, depending on their importance in the revised theoretical models. Planning was introduced in the first step, and working memory was then added in the second. In the third step, long-term memory was incorporated. Finally, visuospatial perception was included.

**Table 4. Hierarchical regression of Planning, Working Memory, Long-Term Memory and Visuoperception on Written Expression**

Models	F	$R^2$	$\Delta R^2$	B	Standar Error	$\beta$	$1 - \beta^2$
<b>Step 1</b>	7.965**	(1,166)	.046	.040			.311 .048
Planning				-.599	.035	.214**	
<b>Step 2</b>	9.210**	(2,165)	.100	.090			.739 .111
Planning				.084	.034	.183*	
WM				.036	.011	.236**	
<b>Step 3</b>	8.615**	(3,164)	.136	.120			.886 .157
Planning				.072	.034	.158*	
WM				.026	.012	.169*	
LTM				.014	.005	.203**	
<b>Step 4</b>	9.039**	(4,163)	.182	.161			.973 .222
Planning				.053	.034	.115	
WM				.022	.012	.146*	
LTM				.013	.005	.191**	
VP				.018	.006	.220**	

**Note:** WS: Writing Sample, WF: Writing Fluency, WE: Written Expression; VP: Visuoperception; WM: Working Memory; LTM: Long-Term Memory. \* < .05; \*\* < .01

The results (table 4) revealed that as the variables are successively incorporated, the model acquires greater explanatory power, increasing its statistical power and effect size, which turned out to be moderate (Cárdenas & Arancibia, 2014).

At Step 1 ( $R^2 = .046$ ,  $p < .001$ ), planning skills explained 4% of the variance. Working memory, at Step 2 ( $R^2 = .100$ ,  $p < .001$ ), increased the model's explanatory power to 10%. According to the standardized beta scores, both variables showed a significant contribution. In Step 3, long-term memory ( $R^2 = .136$ ,  $p < .001$ ) increased the model's explanatory power to 13%. In this model, executive functions and long-term memory predict writing competence, making a significant individual contribution.

In Step 4, with visuospatial perception ( $R^2 = .182$ ,  $p < .001$ ), the model increased its explanatory power to 18%. In this final model, working memory, long-term memory, and visuospatial perception predicted children's writing proficiency. Contrary to expectations, planning was not observed to make a significant contribution. This finding challenges models in which planning, as an executive process, optimizes textual production. In addition, its explanatory power decreased when visuospatial perception was included, which opens a question about the mediating or moderating role of this variable. Studies with more complex statistical models will be necessary to answer this question.

In short, the model built with working memory, long-term memory and visuospatial perception revealed its predictive potential of the ability to write sentences with ideational fluency.

## DISCUSSION

This study aimed to analyse the predictive value of cognitive and executive processes in written expression tasks in Argentine children. The results obtained make interesting contributions in relationship to the study's aims.

The first goal was to describe children's writing ability. The results showed the effect of schooling, which improves this ability.

This effect was especially observed in writing fluency, which is favoured by spelling automation (Wendling, 2007) throughout schooling (Salas & Silvente, 2019). This result supports claims about the substantial improvement in writing tasks starting in fourth grade (Drijbooms et al., 2017).

Some studies reported that, in lower grades, transcription, when it has not been automated, restricts written production (Berninger et al, 1992; Cordeiro et al, 2019). Other studies have indicated that the automatization of transcription frees up cognitive resources (Berninger & Winn, 2006; Fitzgerald & Shanahan, 2000) and allows executive functions to directly support writing (Drijbooms et al, 2015; Salas & Silvente, 2019).

The second goal was to evaluate cognitive and executive processes involved in writing activity. In these cognitive tasks, better scores were obtained in fifth graders, compared to lower grades.

A study that investigated the development of writing and the role of executive functions reported similar results in the increase in executive functioning in the course of schooling (Salas & Silvente, 2019). Another longitudinal study (Drijbooms et al., 2017) provided evidence on the increase in cognitive resources in higher grades that make it possible to write more complex texts.

The third goal was to analyse relations between writing skills and cognitive processes and the effects of the latter on the former.

Planning and working memory were observed to have associations with written expression. Studies with second and fourth grade children showed a direct effect of working memory and planning on the quality of their texts. Children with better working memory and planning produced texts of higher quality and syntactic complexity than children with lower executive performance (Cordeiro et al, 2019; Drijbooms et al., 2017).

Visuospatial perception and long-term memory correlated with all writing measures. This is an interesting contribution, because in the writing task proposed, the students received visual stimuli and executed a motor response, requiring the semantic and syntactic retrieval of the mental lexicon, which was favoured by the automation of spelling (McGrew et al., 2007; Wendling et al., 2007). Studies focusing on visuo-motor processes concluded that the visuospatial sketchpad is an important transcription guide, because the visual permanence of the written trace reduces the demand for executive function resources (Olive & Passerault, 2012).

Finally, the predictive model of cognitive and executive processes revealed a moderate effect.

In studies on writing development, planning, and working memory have been related to syntactic complexity (Drijbooms et al., 2017). There is also consensus on the central role of working memory in organizing information, commanding lexical, syntactic and semantic processes (Abusamra, et al., 2020; Cuetos, 2009; Hayes, 2011; Miranda, 2019; Moreno, 2016). Our results showed that these executive functions allowed children to elaborate sentences and phrases, integrating the information, and applying grammatical rules to obtain a clear text.

Long-term memory increased the predictive power of the model. Information retrieval had a positive effect on written fluency. Long-term memory stores information about grammatical, syntactic, and spelling rules, which must be retrieved to compose the text (Abusamra, et al., 2020). Enunciative, episodic and procedural knowledge is used to connect the retrieved information with working memory to carry out writing processes (García-Madruga, et al., 2012; Mather and Woodcock, 2005).

Lastly, visuospatial perception also proved to have a predictive value. This relationship is consistent with the writing tasks performed because they required auditory and visual stimuli, since writing requires perceptive maturity in both areas (Bravo-Cóppola, 2004; Olive, et al, 2008). This maturity is essential for the automatization of the spelling code and the motor processes. Another study reported the relationship between executive functions and visual processing for the execution of writing, which explains a significant percentage of the variance (Berninger et al., 2016).

Contrary to the claims discussed, our final model reported that planning, although correlated with writing tasks, was not observed to have explanatory weight in writing. This may be because the Porteus Labyrinth Test measures visuospatial planning, which is different from the strategic planning required in writing. In addition, the ability to plan a text is achieved through the school education system. Thus, including strategic planning measures in the model would provide greater clarity on the role of planning. This constitutes one of the limitations of our study.

However, we can highlight the contributions of the study to the knowledge of the role played by working memory, visuospatial processing, and retrieval in long-term memory for the writing of fluent and coherent sentences.

## Limitations

In addition to the predictive weakness of planning, other limitations can be mentioned. First, the absence of a relationship and an effect of attention on writing skills. This could be due to the characteristics of the attention test used, that demanded attention focused on aspects of the visual and morphological stimuli, while in order to write, it is attention directed to linguistic processes that is mainly needed. Future studies should include an attentional test that is relevant to these processes.

There are also limitations related to the writing evaluation method, which represents the most complex methodological aspect of writing studies. The use of standardized batteries allows an objective evaluation, facilitates comparison, and enables the construction of explanatory models. However, it creates some barriers because it fails to include other aspects, such as attitude towards writing and motivation. One way to complete the evaluation is to include the production of narratives or other textual types. This would present a panorama with more elements to access the complexity of writing.

Finally, future studies could use more demanding statistical models including variables such as vocabulary and teaching method.

## Contributions and future directions

Our results show the contribution of executive functions and other cognitive processes to children's writing ability. When jointly considering working memory and planning, it was observed that they predict the writing of adequate sentences with semantic and syntactic content in children from 3rd to 5th grade. Future studies could be carried out with students from higher school grades. This would allow the evaluation of these processes in more proficient writers.

Another contribution was in relation to long-term memory. Since writing demands the use of various contents, adequate recovery capacity and ideational fluency will improve writing activity.

Finally, conducting a study of the cognitive processes involved in writing among Argentine Spanish-speaking children represented another contribution. Previous studies were carried out with children who speak different languages, such as Catalan, Peninsular Spanish (Salas analysis Silvente, 2019), German, Dutch (Drijbooms et al., 2015; Drijbooms et al., 2017) and Portuguese (Cordeiro et al., 2019), but little research has been carried out on Argentine Spanish-speaking children (Miranda, 2019). The differential, phonological and semantic characteristics of their variety of Spanish with respect to other versions of Spanish merit the development of this study.

## Educational implications

The writing tasks carried out in this study allow the design of school interventions: a) the dictation of words to improve manual writing, spelling, and its automation; b) the search for unknown words to increase the semantic store; c) writing about various topics to stimulate the acquisition of syntactic content and planning.

Likewise, the cognitive processes evaluated can be stimulated with execution tasks: a) planning, with the realization of a mental plan of simple tasks; and in writing, articulating the objectives of the text; b) working memory, performing direct and reverse sequencing tasks of numbers or words.

## References

- American Psychological Association (2017). *Ethical Principles of Psychologists and Code of Conduct* (2002, as amended 2010, 2016). American Psychologist. <http://www.apa.org/ethics/code/index.aspx>
- Abusamra, V., Miranda, A., Cartoceti, R., Difalsis, M., Re, A., & Cornoldi, C. (2020). *Batería para la evaluación de la escritura*. Paidós.
- Altemeier, L.; Jones, J.; Abbott, R., & Berninger, V. (2006). Executive Functions in Becoming Writing Readers and Readers Writers: Note Taking and Report Writing in Third and Fifth Grades. *Developmental Neuropsychology*, 29(1), 161-173. [https://doi.org/10.1207/s15326942dn2901\\_8](https://doi.org/10.1207/s15326942dn2901_8)

- Alves, R. A., & Limpo, T. (2015). Progress in written language bursts, pauses, transcription, and written composition across schooling. *Scientific Studies of Reading*, 19(5), 374-391. <https://doi.org/10.1080/10888438.2015.1059838>
- Berninger, V. W., & Winn, W. (2006). Implications of advancements in brain research and technology for writing development, writing instruction, and educational evolution. In C. MacArthur, S. Graham, & J. Fitzgerald (Ed.), *Handbook of writing research* (pp. 96-114). Guilford Press.
- Berninger, V., Abbot, R., Cook, C., & Nagy, W. (2016). Relationship of attention and executive functions to oral language, reading, and writing skills and systems in middle childhood and early adolescence. *Journal of Learning Disabilities*, 50(4), 434-449. <https://doi.org/10.1177/0022219415617167>
- Berninger, V., Yates, C., Cartwright, A., Rutberg, J., Remy, E., & Abbott, R. (1992). Lower-level developmental skills in beginning writing. *Reading and Writing*, 4(3), 257-280 <https://doi.org/10.1007/BF01027151>
- Bohari-Lasaquero, P., Manso-Luengo, A., & Medina-Rivilla, A. (2017). La intervención del bucle fonológico en la actividad ortográfica de alumnos de 2º y 5º de Educación Primaria. *Indivisa. Boletín de Estudios e Investigación*, 17, 93-118. <https://publicaciones.lasallecampus.es/index.php/INDIVISA/article/view/234>
- Bravo-Cóppola, L. (2004). Las destrezas perceptuales y los retos en el aprendizaje de la lectura y la escritura. Una guía para la exploración y comprensión de dificultades específicas. *Actualidades Investigativas en Educación*. <https://doi.org/10.15517/aie.v4i1.9047>
- Cárdenas, M., & Arancibia, H. (2014). Potencia estadística y cálculo del tamaño del efecto en G\*Power: complementos a las pruebas de significación y su aplicación en psicología. *Salud & Sociedad*, 5(2), 210-224. <https://doi.org/10.22199/S07187475.2014.0002.00006>
- Carrada, M., & Ison, M. (2013). La eficacia atencional. Un estudio normativo en niños escolarizados de Mendoza. *PSIENCIA. Revista latinoamericana de Ciencia Psicológica* 5(2), 63-73. <https://doi.org/10.5872/psiencia/5.2.22>
- Chenoweth, N. A., & Hayes, J. R. (2003). The inner voice in writing. *Written Communication*, 20, 99-118. <https://doi.org/10.1177/0741088303253572>
- Cordeiro, C., Limpo, T., Olive, T., & Castro, S. (2019). Do executive functions contribute to writing quality in beginning writers? A longitudinal study with second graders. *Reading and Writing*, 33, 813-833. <https://doi.org/10.1007/s11145-019-09963-6>
- Cuetos, F. (2009). *Psicología de la Escritura*. Editorial Escuela Española.
- Defior-Citoler, S., Martos F., & Herrera, L. (2000). Influencia de las características del sistema ortográfico español en el aprendizaje de la escritura de palabras. *Estudios de Psicología*, 67, 55-64. <https://doi.org/10.1174/02109390060206462>
- Díaz, A., Martín, R., Jiménez, J. E., García, E., Hernández, S., & Rodríguez, C. (2012). Torre de Hanoi: datos normativos y desarrollo evolutivo de la planificación. *European Journal of Education and Psychology*, 5(1), 79-91. <https://doi.org/10.30552/ejep.v5i1.81>
- Dirección General de Escuelas de Mendoza [DGE] (2019). *Documento Curricular para la educación Primaria*. <https://www.mendoza.edu.ar/dcp-primaria/>
- Dirección General de Escuelas de Mendoza [DGE] (2021). *Buscador de Escuelas*. [https://bases.mendoza.edu.ar/intranet2/portal\\_con\\_esc2.asp](https://bases.mendoza.edu.ar/intranet2/portal_con_esc2.asp)
- Drijbooms, E., Groen, M., & Verhoeven, L. (2017). How executive functions predict development in syntactic complexity of narrative writing in the upper elementary grades. *Read and Writing*, 30, 209-231. <https://doi.org/10.1007/s11145-016-9670-8.pdf>

- Drijbooms, E., Groen, M. A., & Verhoeven, L. (2015). The contribution of executive functions to narrative writing in fourth grade children. *Reading and Writing, 28*(7), 989-1011. <https://doi.org/10.1007/s11145-015-9558-z>
- Espósito, A., & Ison, M. (2011). Aportes a los criterios de evaluación de la Figura Geométrica Compleja de Rey (Figura A). *Acta Psiquiátrica y Psicológica de América Latina, 57*(4), 299-307.
- Fitzgerald, J., & Shanahan, T. (2000). Reading and writing realtions and their development. *Educational Psychologist, 35*, 39-50. [https://doi.org/10.1207/S15326985EP3501\\_5](https://doi.org/10.1207/S15326985EP3501_5)
- Flower, L., & Hayes, J. (1981). A Cognitive Process Theory of Writing. *College Composition and Communication, 32*(4), 365-387. <https://doi.org/10.2307/356600>
- García-Madruga, J., Gutiérrez-Martínez, F., & Vila-Chaves, J. (2012). El Desarrollo de la Memoria. In M. Carretero y J. A. Castorina (Comps.), *Desarrollo Cognitivo y Educación II. Procesos del Conocimiento y Contenidos Específicos* (pp.47-69). Paidós.
- García-Pérez, E. M., & Magaz-Lagos, A. (2000). *Escalas Magallanes de Atención Visual*. Albor-Cohs.
- Hayes, J. R. (1996). A new framework for understanding cognition and affect in writing. In C. M. Levy & S. R. Ransdell (Ed.), *The Science of Writing* (pp. 1-27). Lawrence Erlbaum Associates.
- Hayes, J. R. (2011). Kinds of knowledge-telling: Modeling early writing development. *Journal of Writing Research, 3*(2), 73-92. <https://doi.org/10.17239/jowr-2011.03.02.1>
- Hooper, S.R.; Swartz, C.; Wakley, M.B.; de Kuif, R.E., & Montgomery, J. (2002). Executive Functions in Elementary School Children with an without problems in written expression. *Journal of Learning Disabilities, 35*, 57-68. <https://doi.org/10.1177/002221940203500105>
- Introzzi, I., Canet-Juric, L., Montes, S., López, S., & Mascarello, G. (2015). Procesos Inhibitorios y flexibilidad cognitiva: evidencia a favor de la Teoría de la Inercia Atencional. *International Journal of Psychological Research, 8*(2), 60-74. <https://doi.org/10.21500/20112084.1510>
- Korzeniowski, C. (2015). *Programa de estimulación de las funciones ejecutivas y su incidencia en el rendimiento escolar en alumnos mendocinos de escuelas primarias de zonas urbano-marginadas* [Tesis de doctorado inédita]. Facultad de Psicología. Universidad Nacional de San Luis.
- Korzeniowski, C., Cupani, M., Ison, M., & Difabio, H. (2016). School performance and poverty: the mediating role of executive functions. *Electronic Journal of Psychological Research, 14*(3), 474-494. <https://doi.org/10.14204/ejrep.40.15152>
- Korzeniowski, C., Morelato, G., Greco, C., & Monteoliva, J. M. (2020). Improving Executive Functions in Elementary Schoolchildren. *European Journal of Psychology and Educational Research, 3*(1), 59-73. <https://doi.org/10.12973/ejper.3.1.59>
- Marinkovich, J. (2002). Enfoques de proceso en la producción de textos escritos. *Revista Signos, 35*(51-52), 217-230. <http://doi.org/10.4067/S0718-09342002005100014>
- Marino, J.; Fernández, A., & Alderete, A. (2001). Valores Normativos y Validez Conceptual del Test de Laberintos de Porteus en una Muestra de Adultos Argentinos. *Revista Neurológica Argentina, 26*, 102-107.
- Mather, N. & Woodcock, R. (2005). *Woodcock- Johnson III Pruebas de habilidades cognitivas*. Riverside Publishing.
- McGrew, K. S., Dailey, D. E. H., & Schrank, F. A. (2007). Woodcock-Johnson III Normative Update. *Score Differences: What the User Can Expect and Why* (Bulletin No. 9). Riverside Publishing.
- Ministerio de Educación de la Nación Argentina (2017). *Aprender 2017. Informe de Resultados. Primaria*. <https://www.argentina.gob.ar/educacion/aprender2017/reportes-nacionales>



- Ministerio de Educación de la Nación Argentina (2018). *Argentina en PISA 2018. Informe de resultados*. <https://www.argentina.gob.ar/educacion/evaluacion-informacion-educativa/internacionales/pisa>
- Miranda, A (2019). *Desarrollo de la escritura en español: un estudio psicolingüístico* [Tesis doctoral inédita]. Facultad de Filosofía y Letras. Universidad de Buenos Aires.
- Monteoliva, J., Carrada, M., & Ison, M. (2017). Test de percepción de diferencias: estudio normativo del desempeño atencional en escolares argentinos. *Interdisciplinaria*, 34(1), 39-56. <https://doi.org/10.16888/interd.2017.34.1.3>
- Moreno, C. (2016). Escritura de textos narrativos em niños escolares: la importancia de la memoria de trabajo y la memoria a largo plazo. *Revista de Psicología*, 12(24), 7-17. <https://erevistas.uca.edu.ar/index.php/RPSI/issue/view/29/showToc>
- Muñoz-Sandoval, A. F., Woodcock, R. W., Mc Grez, K. S., & Mather, N. (2005). *Batería III Woodcock- Muñoz*. Riverside Publishing.
- Olive, T., & Passerault, J.M. (2012). The Visuospatial Dimension of Writing. *Written Communication*, 29(3), 326-334. <https://doi.org/10.1177/0741088312451111>
- Olive, T., Kellogg, R. T., & Piolat, A. (2008). Verbal, visual and spatial demands during text composition. *Applied Psycholinguistics*, 29, 669-687. <https://doi.org/10.1017/S0142716408080284>
- Portellano-Pérez, J. A. (2005). *Cómo desarrollar la inteligencia: Entrenamiento neuropsicológico de la atención y las funciones ejecutivas*. Somos.
- Posner, M., Sheese, B., Odludas, Y., & Tang Y. (2006). Analyzing and shaping human attentional networks. *Neural Networks*, 19, 1422-1429. <https://doi.org/10.1016/j.neunet.2006.08.004>
- Salas, N., & Silvente, S. (2019). The role of executive functions and transcription skills in writing: a cross-sectional study across 7 years of schooling. *Reading and Writing*, 33, 877-905. <https://doi.org/10.1007/s11145-019-09979-y>
- Scardamalia, M., & Bereiter, C. (1992). Dos modelos explicativos de los procesos de producción escrita. *Infancia y Aprendizaje*, 58, 43-64. <https://doi.org/10.1080/02103702.1992.10822332>
- Smith, S.R., & Zahka, N.E. (2006). Relationship between accuracy and organizational approach on the Rey-Osterrieth Complex Figure and the differential ability scales: a pilot investigation. *Child Neuropsychol*, 12, 383-90. <https://doi.org/10.1080/09297040500350953>
- Tirapu-Ustarróz J.; Muñoz-Céspedes, J.; Peregrín-Valero, C., & Albéniz-Ferrera, A. (2005). Propuesta de un Protocolo para la Evaluación de las Funciones Ejecutivas. *Revista de Neurología*, 41(3), 177-186. <https://doi.org/10.33588/rn.4103.2005054>
- United Nations Educational, Scientific and Cultural Organization (UNESCO) (2020). *¿Qué se espera que aprendan los estudiantes de América Latina y el Caribe? Análisis curricular del Estudio Regional Comparativo y Explicativo 2019*. <https://unesdoc.unesco.org/ark:/48223/pf0000373982>
- Wendling, B. J., Schrank, F. A., & Schmitt, A. J. (2007). *Educational Interventions Related to the Woodcock-Johnson III Tests of Achievement* (Bulletin No. 8). Riverside Publishing.