Do Executive Functions Predict Written Composition? Effects beyond Age, Verbal Intelligence and Reading Comprehension[1].

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SUMMARY

Background:
Several studies have revealed the importance of executive functioning processes for school learning. However, research examining which specific executive functions (EFs) can influence written expression is scarce. This work aimed at i) analyzing the relationship between different EF tasks and different writing tasks (writing a narrative text vs. writing an expository text) and ii) studying which EFs account for unique variance in the composition of written texts, after controlling for age, verbal intelligence (verbal IQ) and reading comprehension.

Material/ Methods:
A total of 186 8-to 15-year old children and adolescents were administered measures of EF, verbal IQ, reading, and writing abilities (i.e., narrative text and expository text). Pearson´s correlations and hierarchical multiple regression analysis were used.

Results:
Domain-specific associations were found between the executive components and the different writing tasks. Hierarchical regressions analysis indicated that only Working Memory (WM) and spontaneous flexibility (i.e., verbal fluency) significantly accounted for variance in the production of a narrative text ($r^2 = .13$, $p < .001$), whereas specific tasks that measure spontaneous flexibility (i.e., verbal and non-verbal fluency), WM and inhibition, explained a percentage of the variance in the composition of an expository text ($r^2 = .24$, $p < .001$).

Conclusions:
The results support the hypothesis that EF contributes to academic performance in school-age children and highlights the importance of considering EF as a process that contributes to written composition.

Keywords: child neuropsychology, written composition, narrative text, expository text

INTRODUCTION

Executive Functions (EFs) include a set of cognitive processes necessary for goal-directed behavior (Luria, 1966; Stuss & Benson, 1986). It is considered a multidimensional construct that encompasses three separate but related sub-processes, namely (i) working memory (WM), (ii) inhibition and (iii) cognitive flexibility (Miyake et al., 2000). These cognitive processes enable one to self-regulate behaviour, to reflect and resolve problems in order to adapt to environmental demands and effectively operate within different fields.

In recent years, studies of EF in youth populations have received special attention, given that these processes influence academic performance in children and predict their future outcomes in social, emotional and cognitive terms. Research in the field of child neuropsychology has showed that EFs are essential for children's independence and autonomy in daily functioning (Rosenberg, 2014); these higher-order processes are related to children's motor abilities (Livesey, Keen, Rouse, & White, 2006) and further promote their socio-emotional competencies (Riggs, Jahromi, Razza, Dillworth-Bart, & Mueller, 2006), namely social skills, peer relationships and the ability to delay gratification. Additionally, EFs predict both the development of pre-academic skills (Espy, McDiarmid, Cwik, Stalets, Hamby, & Senn, 2004; Shaul & Schwartz, 2014) and learning and academic achievement by school age (Jacobson Williford, & Pianta, 2011; St Clair-Thompson & Gathercole; 2006; Thorell, Veleiro, Siu & Hiwa Mohammadi, 2013).

Though the importance of the EF construct is not restricted to the school environment, research in the field of neuroeducation has been particularly prolific, due to its usefulness for understanding and providing solutions for certain learning difficulties. This is the case to the extent that classifications such as that of the *National Center for Learning Disabilities* (NCLD) include EF deficits as a factor associated with learning difficulties. A growing body of research in this area has demonstrated the importance of executive processes in learning. Specifically, there is considerable evidence regarding the central role that the former play in the performance achieved in different reading, mathematics and writing tasks (see e.g., Arán Filippetti & Lopez, 2014; Bull, Espy, & Wiebe, 2008; Hooper, Swartz, Wakely, de Kruif, & Montgomery, 2002; Sesma, Mahone, Levine, Eason, & Cutting, 2009), being the latter the one that has received the least attention.

The study of written expression among school-age children is highly relevant, given its importance for future success at both academic and employment level. According to Graham and Perin (2007), those adolescents who have not learned how to write correctly are at a disadvantage when it comes to accomplishing school requirements, their chances to attain university are fewer and this insufficiency can impede their future professional outcomes. Figures from different studies about writing difficulties in children and adolescents show an astounding prevalence, with 6 to 22% of children in the US exhibiting significant writing problems (Hooper, Swartz, Montgomery, & Reed, 1993; Mielnik, Łockiewicz, Bogdanowicz 2015). Moreover, among the clinical population, learning difficulties in

written expression are twice as common as problems in reading and mathematics (Mayes & Calhoun, 2006). Higher-order cognitive problems are at the root of many writing difficulties in children with neurofibromatosis (Gilboa, Josman, Fattal-Valevski, Toledano-Alhadef, & Rosenblum, 2014) and cerebral palsy (Bumin & Kavak, 2010). Despite its proven implication, the understanding of those processes that influence writing, mainly in terms of its neurocognitive substrates, has been left behind in comparison to other academic domains, such as reading (Hooper et al., 2002).

Among the studies that have examined this aspect is that by Berninger and Rutberg (1992), which showed that the evaluation of the motor planning and programming of complex sequential movements in children would be useful for the early detection of writing disabilities (see also Pachalska et al. 2015). In turn, Swanson and Berninger (1996) found that WM tasks that reflect executive processes are significantly associated with different measures of writing, particularly with those related to text production. Hooper et al. (2002) also demonstrated the importance of executive processes in the written expression, specifically those executive domains of initiation, set shifting and sustaining. By using different tasks to evaluate both the EFs (i.e., inhibition, verbal fluency (VF), planning, switching attention and WM) and the written processes (i.e., note taking and written reports), Altemeier, Jones, Abbott and Berninger (2006) found that inhibition predicted note taking in 3rd-grade and 5th-grade students while VF and planning predicted the report-writing task in 3rd grade and only VF predicted that task in 5th grade. Finally, organizational skills would be another executive component to consider in the study of the written expression, as demonstrated by Rosenblum, Aloni and Josman (2010) who found that this single measure accurately classified 81% of a group of children with Dysgraphia in comparison to the control group.

While there is further research analysing the relationship between EFs and writing, most of these studies address this relationship by studying just some of the executive abilities, with those works that are based on a model of EFs which assess all of its components and use different tasks to value both each executive domain and the production of written texts being rare. Hence, this work seeks to expand on the results of previous research when analysing the specific contribution of EFs on the production of written texts, considering the executive processes of WM, inhibition and cognitive flexibility (both spontaneous and reactive flexibility) (Miyake et al., 2000). Besides, as those studies in the area included planning ability in order to analyze its relation with writing abilities (see e.g., Berninger & Rutberg, 1992 and Alteimer et al., 2006) we also considered this EF in the study. To assess written production, we consider the writing of both a narrative and an expository text. Since linguistic and literacy skills (i.e., reading) become factors that can influence written composition in children (see e.g., Kim, Otaiba, Sidler, & Gruelich, 2013), the child's verbal skills (verbal IQ) and their level of reading comprehension will be controlled with the aim of understanding the unique contribution of EFs over and above the variance explained by these abilities.

HYPOTHESIS

Based on the previous theoretical and empirical evidence, the following hypotheses were formulated:

Hypothesis 1. Considering that previous studies have shown there would exist certain domain-specific associations among the EFs and academic abilities, i.e., there are specific EFs more strongly associated with performance in different academic abilities than others (see e.g. Bull et al., 2008 and St Clair-Thompson & Gathercole, 2006), it is hypothesized that the different executive processes do not have the same weight in writing performance.

Hypothesis 2. Since the demand on executive processes would partly depend on the cognitive operations underlying the different writing activities (see e.g., Altemeier et al., 2006; Swanson & Berninger, 1996 and Piola, Olive & Kellogg, 2005), and considering that writing an expository text is more difficult than writing a narrative one, for it implies having access to relevant information on a topic (Cuetos Vega, Ramos Sánchez & Ruano Hernandez, 2004), it is hypothesized that there is a greater association between EFs and writing expository texts than between these cognitive processes and writing narrative texts.

METHOD

Participants

The sample was made up of a total of 186 children and adolescents between the ages of 8 and 15 years, living in Argentina. From the information obtained in the educational establishment, the criteria for inclusion were as follows: (1) children and adolescents with no known history of neurological or psychiatric treatment; (2) who attend school regularly; (3) without grade repetition. Prior to the administration of cognitive tasks, the K-BIT test was used (Kaufman & Kaufman, 2000) in order to establish that the children had a performance within the range expected for their age group. Intellectual functioning (i.e., composite IQ) was found to be within the range expected for the children (M = 94.65; SD = 10.92).

Instruments

Intelligence

KBIT, Kaufman's Brief Test of Intelligence (Kaufman & Kaufman, 1990, Spanish adaptation by Cordero & Calonge, 2000).

It provides a measure of verbal or crystallized intelligence (Gc) and non-verbal or fluid intelligence (Gf) and consist of two subtests: (1) *vocabulary*, which includes part A to evaluate expressive vocabulary and part B to evaluate *definitions* and (2) *matrices* (Gf). By summing the scores obtained in both subtests, a measure of composite IQ can be obtained.

Executive Functions

(1) Working memory

Digit Span and Letter–Number Sequencing Subtests of the WISC-IV (Wechsler Intelligence Scale for Children – Fourth Edition) (Wechsler, 2003, Spanish Adaptation TEA, 2005). This provides a composite index of WM. It is composed of two main subtests: *Digits (D)* that provide a measure of immediate verbal retention when evaluated with direct digits, and the maintenance and manipulation of information (working memory) when inverse numbers are used; *Letters and numbers (LN)* which consists in the reading by the examiner of a series of scrambled numbers and letters and the child must recall that series in an ordered sense from lowest to highest and the letters in alphabetical order.

(2) Inhibition

Stroop Color–Word Test (Golden, 1978, Spanish Adaptation TEA, 1999). This provides a measure of resistance to interference and response inhibition. It consists of three sheets. On the first sheet, the words 'red', 'green' and 'blue' are randomly sorted and written in upper case black. The second sheet presents elements arranged in the same way, without the possibility of reading (xxxx), printed randomly in blue, green or red ink. The last sheet included the same set of words as the first sheet but printed in the colours of the second one, so that the colours do not match the meaning of the word. Thus, the subject must inhibit the reading of the word in order to name color. The test-retest reliability is .86 for the Word sheet, .82 for the Color sheet, and.73 for the Color-word sheet (Golden, 1975, cited in Golden, 1999).

Knock and Tap, NEPSY (Korkman, Kirk, & Kemp, 1998). This evaluates self-regulation and inhibition. The child must suppress a motor action in order to produce a motor response in conflict. NEPSY battery has been normalized in Spanish-speaking (Aguilar-Alonso, Torres-Viñals, & Aguilar-Mediavilla, 2014). Several recent studies have used this task to assess the inhibition component of EF in English-speaking children (Pratt, Leonard, Adeyinka, & Hill, 2014), French-speaking children (Mainville, Brisson, Nougarou, Stipanicic, & Sirois, 2015) and Spanish- speaking children (Aguilar-Alonso, & Moreno-González, 2012).

(3) Cognitive flexibility (reactive and spontaneous flexibility)

Wisconsin Card Sorting Test (WCST) (Heaton, Chelune, Talley, Kay, & Curtiss, 1993, Spanish Adaptation TEA, 1997). This provides a measure of executive function, particularly of reactive cognitive flexibility and categorization abilities. For a start, the participant is presented with four stimulus cards. Then, the participant receives a pile of extra cards and he/she is asked to match each card to one of the stimulus cards. Participants are told whether their options are right or wrong, the moment they place a card; categories are not given to participants while they are classifying. In a CFA study, it was noticed that the WCST strongly reflected the EF construct (Greve, Stickle, Love, Bianchini, & Stanford, 2005). The indicator included in the study was the number of categories completed (CC).

Trail Making Test (TMT).

This is made up of two subtests, part A and part B. It allows the obtaining of a measure of sequencing, attention and motor functioning, visual seeking and cognitive flexibility (Spreen & Strauss, 1998), specifically, reactive flexibility. For both subtests, form A and form B, the time and the number of errors are recorded. The test-retest reliability coefficient ranges from .60 to .90 (Spreen & Strauss, 1998). By means of Exploratory Factor Analysis and Confirmatory Factor Analysis techniques, it has been shown that the task loads on the flexibility factor of EF (Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003).

Semantic Verbal Fluency Test (SVF, fruits and animals), and Phonological Verbal Fluency (PVF, letters F, A, and S).

This provides a measure of spontaneous flexibility. The task consists in asking the participants to name all of the words that they remember, belonging to certain categories (SVF) or starting with a particular letter (FVF) in 60 seconds. There are norms available for Spanish-Speaking children (Arán Filippetti & Allegri, 2011; Ardila & Rosselli, 1994).

Five-Point Test (Regard, Strauss, & Knapp, 1982).

This enables to obtain a measure of non-verbal or visual fluency, defined as the capacity of the subject to generate original ideas. The task requires spontaneous cognitive flexibility. The test-retest reliability for the number of unique designs is .77 (Tucha, Aschenbrenner, Koerts, & Lange, 2012).

(4) Planning

Porteus Mazes (Porteus, 1965, Spanish Adaptation TEA, 2006).

This is made up of twelve mazes of increasing complexity. The test enables the evaluation of planning abilities. In each maze, the participant must indicate the way from a starting point to an exit and must elude blind alleys and dead ends, with no backtracking permitted.

Mexican Pyramid (ENI, Child Neuropsychological Assessment) (Matute, Rosselli, Ardila, & Ostrosky-Solís, 2007).

This allows one to establish measures of planning and organization. The child must use three wooden blocks under certain restrictions, with the aim of building a series of designs previously offered as models.

Reading and Writing

Reading comprehension subtest, ENI battery (Matute et al., 2007).

The children must read a text mentally and then answer a series of questions relating to its content. It enables one to assess reading and speed comprehension.

PROESC, Battery for the evaluation of writing processes (Cuetos Vega et al., 2002).

This allows the evaluation of the main processes involved in writing. The aspects to be evaluated are (1) writing a narrative text and (2) writing an expository text. In both aspects, value is attributed for the content, coherence, and organization of the written text. Specifically, for the production of a *narrative text*, content and coherence-style are scored from 1 to 15 and for the writing of an

expository text, content and presentation are rated by points ranging from 1 to 5. The highest score for each subtest is 10. The alpha coefficient of the PROESC battery is .82 (Cuetos Vega et al., 2002).

Ethics procedures

Interviews were conducted with school principals, to whom the details of the research were explained. Then, a note was sent to the children's parents or legal guardians asking for their permission. It was clarified that participation was voluntary and anonymous. Finally, the written consent of all the parents or legal guardians was obtained before the evaluation was commenced.

Statistical Procedures

Descriptive statistics were used: medians and standard deviations were calculated for each of the cognitive tasks employed. To analyse the association between Verbal IQ, Reading Comprehension, EFs and the different writing tasks, Pearson correlations were used. Finally, to understand which EFs predict the different writing tasks, after controlling for age, verbal IQ, and the level of reading comprehension, hierarchical regression analysis was used. All of the analyses were conducted using the Windows 20.0 version of the SPSS statistical package.

RESULTS

Table 1 shows the descriptive statistics for the EF measures, control variables (verbal IQ and reading comprehension) and the writing tasks, for the total sample of children and adolescents.

The associations between verbal IQ, reading comprehension and the writing tasks are presented in Table 2. Performance in writing tasks is associated both

Table 1. Descriptive Statistics for Cognitive Tasks

Variable	Task	Indicator	*M*	*DS*
Verbal IQ	K-Bit	Vocabulary	101.38	10.89
Reading Comprehension	ENI subtest	Reading Comprehension	4.24	1.72
Writing	Proesc	Narrative Text	4.61	1.93
		Expository Text	2.46	1.34
Working Memory	WISC-IV	Digits	17.90	4.00
		Letter-number	17.55	3.73
Inhibition	Stroop	Word-color sheet	30.10	9.63
	Knock and Tap	Correct responses	28.30	1.71
Cognitive Flexibility	Trail Making Test	TMT B time	45.47	18.53
	WCST	Complete Categories	5.43	1.04
	Five Point Test	Unique Designs	28.15	9.94
	Verbal Fluency Task	Total Semantic and Phonological Fluency	47.76	15.40
Planning	Porteus mazes	Total mazes	12.56	2.23
	Mexican Pyramid	Designs with minimum number of movements	8.06	1.82

with reading comprehension and verbal IQ, displaying a stronger association with the latter variable. Specifically, verbal IQ and reading comprehension scores are associated with the production of both narrative texts (range from $r = .255$ to $r = .394$) and expository texts (range from $r = .230$ to $r = .411$).

Table 3 presents the Pearson correlations between the EF measures and the different writing tasks. All the EF measures, except the WCST-CC, are associated both with writing narrative and expository texts. Specifically, tasks that evaluate WM, inhibition, spontaneous and reactive cognitive flexibility, and planning were all associated with higher scores in tasks that assess the writing of a narrative text (range from $r = .179$ to $r = .565$) and that of an expository text (range from $r = .184$ to $r = .600$). Note that there was a stronger association between EF and the more complex aspects of writing tasks related to writing coherence and presentation.

Finally, hierarchical regressions analyses were used to analyse the contribution of EFs to writing, after controlling for age, reading comprehension and verbal IQ. Only results at the ≤ .01 levels are considered to be statistically significant, due to the size of the sample. Tests of multicollinearity were satisfactory with all the variance inflation factors (VIF) being less than 4.00 and the tolerance of variables all near to 1.00. The first hierarchical regression models included the following blocks: (1) age, (2) reading comprehension and verbal IQ, and (3) EF

Table 2. Correlations between Reading Comprehension, Verbal IQ and Writing Abilities

	NT Content	NT Coherence	NT Total	ET Content	ET Presentation	ET Total
Reading Comprehension	.270**	.255**	.284**	.230**	.302**	.297**
Verbal IQ	.336**	.380**	.394**	.294**	.436**	.411**

Note. NT= Narrative Text; ET= Expository Text
** $p < .01$.

Table 3. Correlations between EF measures and Writing Abilities

	NT Content	NT Coherence	NT Total	ET Content	ET Presentation	ET Total
Digits WISC IV	.370**	.525**	.503**	.420**	.528**	.529**
Letter-Number WISC IV	.360**	.560**	.521**	.414**	.463**	.486**
Stroop Word-color sheet	.344**	.504**	.478**	.470**	.518**	.547**
Knock and Tap	.179*	.271**	.254**	.234**	.242**	.263**
Trail Making Test	-.302**	-.418**	-.404**	-.338**	-.363**	-.387**
WCST-CC	.062	.161*	.131	.184*	.200**	.213**
Five Point Test	.333**	.491**	.465**	.427**	.536**	.537**
Verbal fluency	.426**	.565**	.554**	.454**	.600**	.590**
Porteus Maze	.211**	.288**	.279**	.217**	.352**	.322**
Mexican Pyramid	.196**	.221**	.230**	.217**	.145*	.194**

Note. NT= Narrative Text; ET= Expository Text
* $p < .05$. ; ** $p < .01$.

measures (WM, inhibition, cognitive flexibility and planning). The whole model explained 39% of the variance in writing a narrative text and 46% of the variance in writing an expository text. EFs of WM and spontaneous flexibility (i.e., verbal fluency) accounted for a significant amount of variance (7%) in writing a narrative text, over and above the variance explained by age and verbal IQ, while WM, inhibition of verbal responses and spontaneous flexibility (i.e., non-verbal Fluency and VF), explained 16% of the variance in writing an expository text over and above the variance explained by age and verbal IQ. Specifically, higher scores on tasks assessing WM, inhibition and spontaneous flexibility were associated with higher scores on writing tasks. Note that for the writing of an expository text, the EFs explained a higher percentage of variance than the verbal IQ. Moreover, when the EFs were entered into Block 3, verbal IQ ceased to be a significant predictor both for writing a narrative text (β = .11, p = .147) and for writing an expository text (β = .06, p = .410). Seemingly, the association between verbal IQ and writing might be due to the variance shared with the EFs. Table 4 shows

Table 4. Summary of Hierarchical Regression Predicting Written Composition, including EFs in Block 3

Dependent	Predictor	R^2	ΔR^2	β	p
Narrative Text	Block 1				
	Age	.25	.25	.50	**< .001**
	Block 2				
	Reading Comprehension	.31	.07	.02	ns
	Verbal IQ			.26	**< .001**
	Block 3				
	WM	.39	.07	.26	**.032**
	Stroop			.08	ns
	Knock and Tap			-.03	ns
	TMT-B			-.02	ns
	WCST-CC			-.06	ns
	Porteus mazes			.02	ns
	MP			-.03	ns
	FPT			.07	ns
	VF			.26	**.012**
Expository Text	Block 1				
	Age	.21	**.21**	**.46**	**< .001**
	Block 2				
	Reading Comprehension	.30	**.08**	.04	ns
	Verbal IQ			.29	**< .001**
	Block 3				
	WM	.46	**.16**	**.24**	**.035**
	Stroop			**.25**	**.005**
	Knock and Tap			-.04	*ns*
	TMT-B			.06	*ns*
	WCST-CC			.01	*ns*
	Porteus mazes			.08	*ns*
	MP			-.09	*ns*
	FPT			**.21**	**.013**
	VF			**.32**	**.001**

Note. WM= Working Memory (WISC IV); Stroop = color-word interference score of the Stroop test; Knock and Tap = correct responses; TMT-B = TMT B time; WCST-CC= Complete Categories of WCST; Porteus mazes = total number of mazes completed; MP = Mexican Pyramid -correct designs with minimum number of movements-; FPT= Five Point Test; VF = Verbal Fluency.

Table 5. Summary of Hierarchical Regression Predicting Written Composition, including EFs in Block 2

Dependent	Predictor	R^2	ΔR^2	β	p
	Block 1				
	Age	.25	**.25**	**.50**	**< .001**
	Block 2				
	WM	.37	**.13**	**.30**	.010
	Stroop			.11	ns
	Knock and Tap			-.03	ns
	TMT-B			-.03	ns
	WCST-CC			-.05	ns
Narrative Text	Porteus mazes			.02	ns
	MP			-.02	ns
	FPT			.06	ns
	VF			**.29**	.003
	Block 3				
	Reading Comprehension	.38	.01	-.02	ns
	Verbal IQ			.12	ns
	Block 1				
	Age	.21	**.21**	.46	**< .001**
	Block 2				
	WM	.46	**.24**	.27	.013
	Stroop			.26	.002
	Knock and Tap			-.04	ns
Expository Text	TMT-B			.05	ns
	WCST-CC			.01	ns
	Porteus mazes			.08	ns
	MP			-.08	ns
	FPT			.21	**.014**
	VF			.34	**< .001**
	Block 3				
	Reading Comprehension	.46	.01	.01	ns
	Verbal IQ			.07	ns

Note. WM= Working Memory (WISC IV); Stroop = color-word interference score of the Stroop test; Knock and Tap = correct responses; TMT-B = TMT B time; WCST-CC= Complete Categories of WCST; Porteus mazes = total number of mazes completed; MP = Mexican Pyramid -correct designs with minimum number of movements-; FPT= Five Point Test; VF = Verbal Fluency.

a summary of the hierarchical regression analyses of the variables that predict performance on the writing tasks.

Based on these results, hierarchical regressions models were performed including the EFs in Block 2, and reading comprehension and verbal IQ in Block 3 (see Table 5). The results indicate that EFs explain a higher percentage of the variance in both writing a narrative text (r^2= .13), and writing an expository text (r^2= .24), while verbal IQ and reading comprehension did not contribute significantly to the prediction of written composition in Block 3. This indicates that of the variables included in these models, only EFs account for a unique variance in writing both narrative and expository text.

DISCUSSION

Writing skills are essential for both academic and working success. There is evidence that they assist learning (see Bangert-Drowns, Hurley, & Wilkinson,

2004) and WM ability (Klein & Boals, 2001) and would enable people to obtain psychological benefits for it becomes a tool that can be used for exploring the inner-sense, fighting loneliness and narrating personal experiences (Graham & Perin, 2007). Yet, though writing is necessary for achieving numerous goals, only a few studies have actually analysed the specific executive processes necessary for writing texts at school level, becoming evident that WM is the cognitive EF most analysed in relation to the writing process (see e.g. Kellogg, 1996, Kellogg 2004). Besides, those studies which have analysed the influence of different executive processes on academic performance have primarily dealt with mathematics (see e.g., Bull et al., 2008; Bull, Espy, Wiebe, Sheffield, & Nelson, 2011) and to a lesser extent with reading (see e.g., Locascio, Mahone, Eason, & Cutting, 2010; Sesma et al., 2009) and writing (see e.g., Altemeier et al., 2006; Hooper et al., 2002).

One of the main objectives of this study was to analyse the relationship among different EF tasks and the production of written texts, as well as examining which specific EF accounts for unique variance in different writing tasks, beyond the variance explained by age, verbal IQ and reading comprehension.

Primarily, correlation analyses showed that verbal IQ and reading comprehension are related to writing performance in children. This results actually confirm previous studies that also found that linguistic abilities (Gilboa et al., 2014; Kim et al., 2013) and reading (Berninger & Abbott, 2010; Kim et al., 2013) are related to different writing tasks. Pearson´s correlations also indicated that EFs were associated with writing performance, both with the writing of a narrative and an expository text. This information supports previous studies that have demonstrated there exists an association between EFs and academic performance (see e.g., Arán Filippetti & Lopez, 2014; Thorell et al., 2013; St Clair-Thompson & Gathercole, 2006). More specifically, in the academic area of writing, our results provide additional support to previous studies as regards the role that processes such as WM (Swanson & Berninger, 1996), verbal fluency (VF) and inhibition (Altemeier et al., 2006) play in writing. Interestingly, a stronger association with the most complex aspects of written tasks as regards written coherence and presentation was found, including issues such as the logical flow of ideas, the overall meaning of the story, the using of complex phrases throughout the text and organization, among others. This suggests that in order to produce cohesive and coherent texts, higher-level cognitive processes are necessary.

Hierarchical regression analyses showed that WM and spontaneous flexibility accounted for unique variance in writing a narrative text, while WM, inhibition and spontaneous flexibility accounted for a unique percentage of variance in writing expository texts over and above the contributions of age, and verbal IQ. Remarkably, though verbal IQ explained a percentage of the variance in both writing tasks, reading comprehension was not a significant predictor. Similar results were informed by Kim et al. (2011), who found that reading comprehension was not related to writing performance in kindergarteners, after controlling for the effects of other variables such as spelling. As the authors suggest, the vari-

ance explained by other potential intervening variables, as well as the tasks employed to evaluate reading comprehension might explain these findings. On the other hand, though verbal IQ was a significant predictor of writing, it ceased to be an important one for both the writing of a narrative (β = .11, p = .147) and an expository text (β = .06, p = .410) when the EFs were entered into Block 3 of the regression model. Thus, WM and spontaneous flexibility would be the executive processes involved in the writing of both type of texts, even more than verbal IQ or reading comprehension. Apparently, those differences in processes such as the retention and manipulation of information and spontaneous cognitive flexibility would become the main executive processes that would partly explain the individual variations in the production of creative writing tasks.

The importance of WM for academic performance has been demonstrated in numerous previous studies, being the EF – in relation to learning – the one that has received the greatest attention. Thus, several studies have identified the central role that WM plays in the performance in mathematics (Alsina & Saiz, 2004; Anderson, 2008; Holmes & Adams, 2006), reading (Baqués & Sáiz, 1999) and writing (Hooper et al., 2002; Kellog, 1996; Swanson y Berninger, 1996). Furthermore, distinct studies in this line have suggested that the different components of WM (according to the Baddeley & Hitch model, 1974) would not equally influence academic performance. Particularly, as regards writing, it has been suggested that higher level writing processes would impose demands on the central executive component of WM (Olive, Kellogg, & Piolat, 2008; Vanderberg, & Swanson, 2007) and that different written sub-processes would be selectively associated with the phonological loop and the visuospatial sketchpad components. Specifically, during the writing process, when images are visualized, the planning process would need access to a visuospatial sketchpad, whereas the translation and revision processes (i.e., reading) would impose demands on the verbal component of WM (Kellogg, 1996). Vanderberg and Swanson (2007) recently observed that written processes would be more strongly connected with the attention control function of WM than with that of storing information. Given the tasks used in the present study, our results provide additional support for the role of both the central executive component of WM (inverse digits and letters-numbers), and the phonological loop (direct digits) in written processes.

Verbal Fluency tasks are among those measures most commonly used to evaluate executive functioning, and more specifically the subject's spontaneous flexibility (Eslinger, Biddle, Pennington, & Page, 1999). Different studies have demonstrated the role of the former tasks in academic abilities, though most research has examined primarily their relation with Mathematics. Thus, for instance, the studies by Rosselli, Ardila, Matute and Inozemtseva (2009) and Loehr, Miller, DeCaro, and Rittle-Johnson (2013) have consistently shown that VF predicts a unique percentage of variance in mathematics abilities. Altemeier et al., (2006) also found that VF predicted the report-writing task in 3rd - and 5th- grade students. Our results provide additional evidence as regards the relationship between VF and writing, extending this evidence to different writing tasks, such as writing

narrative and expository texts. This association can be explained by the fact that VF involves language generation (Altemeier et al., 2006). However, given that spontaneous flexibility requires not only inhibiting responses and automatic strategies but also coming up with divergent and creative thoughts (Slachevsky et al., 2005), it could be hypothesized that VF is not only associated with writing texts because of their verbal nature, but rather that these cognitive resources which require the generation of words, would be also involved in producing written texts. Supporting this hypothesis, it was found that non-verbal fluency, a task that also evaluates the subject's spontaneous flexibility but lacks a verbal component, also predicted writing abilities and especially when writing expository texts. Consistently, it was this type of flexibility (i.e., spontaneous) – closely linked to the concept of creativity (Ebersbach & Hagedorn, 2011) - the one related to the production of written tasks, but not reactive flexibility. This might be explained by the fact that the tasks used to evaluate the production of written texts require creative writing (see Cuetos et al., 2004).

Finally, another executive process that would be involved in producing written texts, and particularly expository ones, is inhibition. Altemeier et al. (2006) have consistently found that inhibition is one of the executive components that influences writing. The tasks used in the present study to evaluate inhibition processes were the Knock and Tap and the Stroop tests, which evaluate the inhibition of motor responses and the inhibition of verbal responses respectively. It has been suggested that the Stroop test evaluates cognitive inhibition, which would be a more advanced process in development compared to a more primitive motor inhibition (Espy et al., 2004). Interestingly, the results of the correlation carried out by this work indicate that there is a stronger relationship between the Stroop test and writing. Moreover, the only task resulting to be a significant predictor in the regression model was the Stroop test. These results suggest that the written production would mainly depend on the cognitive component of inhibition, which consists in suppressing irrelevant information from WM (Nigg, 2000). Probably, the inhibition ability together with WM contribute to writing performance, for they are processes that interact as the WM activation influences the extent of inhibition of other alternative responses (Roberts & Pennington, 1996). As such it could be hypothesised that the ability to delete information from WM that is not relevant for writing an expositive text would be a key process when writing. According to Altemeier et al. (2006) inhibition would be necessary for the selection of relevant information and the inhibition of prepotent responses that could lead to including irrelevant details in writing.

It is important to highlight the fact that the different tasks of written production would be associated with different executive processes, implying that the writing of expository texts represents a greater level of difficulty and cognitive effort with respect to narrative ones. Only WM and spontaneous flexibility explained 13% of the variance in writing narrative texts, while WM, spontaneous flexibility and verbal response inhibition explained 24% of the variance in expository texts. This is consistent with that indicated by Cuetos Vega et al. (2004) who mention that

the structure of narrative texts would be simpler as they have the well-defined components that children acquire at an earlier age (i.e., introduction, body, and conclusion), whereas expository texts are more difficulty because they require one to organize knowledge in a totally different way. Previous studies have also demonstrated that the cognitive effort required by writing varies depending on the requirements of the task. For instance, Swanson and Berninger (1996) found that WM is associated with different writing measures, mainly with those related to text generation. Piola et al. (2005) observed that note taking requires a greater cognitive effort than learning or reading, but less effort than the creative production of an original text. More recently, Altemeier et al (2006) found that different EFs contribute to writing depending on the task used (i.e., note taking vs. report-writing tasks); inhibition is mainly associated with note taking while VF is more important for the report-writing task. Therefore, it would seem that the degree of demand on executive processes would partly depend on the cognitive processes underlying the different writing tasks.

In summary, our results support the hypothesis that EFs become an essential pillar for academic performance. In accordance with that identified in the present study, specific cognitive domains contribute significantly to writing performance, even after controlling for age, verbal IQ and reading comprehension. Thus, writing texts would require each of those components of Miyake´s EF model: (1) the ability to maintain and manipulate online information (i.e., WM) to organise information coherently without repeating or mixing ideas, (2) the ability to generate new ideas and seek and select appropriate words from one's internal lexicon (i.e., spontaneous flexibility), and (3) the inhibition of irrelevant information previously activated from the WM (i.e., inhibitory component), mainly that of a verbal nature. Though, it should be noted that our findings emphasize the importance of using different measures to evaluate each domain of EF when analysing their relationship with academic abilities, as the nature of each EF task (e.g., verbal and non-verbal), as well as those of writing (e.g., expository vs. narrative text; creative writing vs. modelling writing) would be a relevant factor when explaining this association.

This study has important clinical and educational implications. First, the analysis in non-clinical populations of the relationship between a student's cognitive profile and his/her level of academic achievement gains significant value, considering that the individual variations in academic performance can be explained by individual differences in executive functioning, even when the difficulties fall within a normal range without reaching clinical extremes. From this perspective, a poor executive functioning represented by difficulty in organizing ideas, manipulating online information and inhibiting irrelevant information could interfere in the development of children's writing abilities. Moreover, understanding those predominant aspects of the EF that have the greatest effect on writing performance, promotes the correct diagnosis of writing difficulties, as well as the design of intervention strategies addressing the cognitive processes involved. According to Cuetos Vega et al. (2004), in order to improve writing processes, teachers

need to first know the processes involved in writing, and after being properly acknowledged, identify those that the student does not master. Precisely, results from this study reveal the importance of considering executive processes, specifically the spontaneous cognitive flexibility and WM, as indicators for an early identification of difficulties in written production, even over children's verbal intellectual abilities and their level of reading comprehension. They also show the need to develop and implement curricular changes that support and stimulate the development of executive abilities in children from the beginning of formal schooling, in order to ease the development of their writing abilities throughout their educational cycle.

CONCLUSIONS

The results support the hypothesis that EF contributes to academic performance in school-age children and highlights the importance of considering EF as a process that contributes to written composition.

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