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Word Writing and Cognitive Predictors in Spanish at the Age of Seven

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Abstract

Interest in the cognitive precursors of literacy has been increasing in recent years since reading and writing are essential components of functional learning in the first years of schooling and of school success in later educational stages. However, it can be observed that while studies on the relationship between cognitive variables and reading are frequent, those carried out about writing are scarcer and in different languages and ages. The purpose of this study is to explore the joint contribution made by certain cognitive variables, measured at the ages of 6 and 7, to word writing among Spanish children in the second year of Primary Education (7 years old). In this longitudinal study, 116 Spanish-speaking pupils participated, from schools located in an average socio-cultural area, without special educational needs. Participants were evaluated in terms of their letter knowledge, phonological awareness, phonological memory, and alphanumeric and non-alphanumeric rapid automatised naming at 6 and 7 years of age, and word writing at 7 years of age. Descriptive-exploratory analyses, bivariate analyses, and multivariate regressions were modelled. In general, the findings show a different contribution for the cognitive variables considered in word writing at the age of seven, although this contribution does not vary substantially between the ages of 6 and 7 among Spanish pupils. Phonological knowledge at 6 and 7 years of age is the variable that best predicts the writing of words at 7 years. The contribution of non-alphanumeric speed naming remains constant and alphanumeric speed naming does not contribute to the explanation of writing at this age. Phonological memory at 6 years of age contributes to the explanation of writing at the age of 7 and letter knowledge contributes at the age of 7. These results have implications for educational practice and for the theory of writing acquisition in transparent languages.

Keywords Letter knowledge · Phonological awareness · Rapid automatised naming · Phonological memory · Writing · Spanish

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Résumé
L'intérêt pour les précurseurs cognitifs de la littératie s'est accru ces dernières années puisque la lecture et l'écriture sont des composantes essentielles de l'apprentissage fonctionnel au cours des premières années de scolarité et de la réussite scolaire aux étapes ultérieures de l'enseignement. Cependant, on peut observer que si les études sur la relation entre les variables cognitives et la lecture sont fréquentes, celles menées sur l'écriture sont plus rares et dans des langues et des âges différents. L'objectif de cette étude est d'explorer la contribution conjointe de certaines variables cognitives, mesurées aux âges de 6 et 7 ans, à l'écriture de mots chez les enfants espagnols de deuxième année de l'enseignement primaire (7 ans). Dans cette étude longitudinale, 116 élèves hispanophones ont participé, issus d'écoles situées dans une zone socioculturelle moyenne, sans besoins éducatifs particuliers. Les participants ont été évalués en termes de connaissance des lettres, de conscience phonologique, de mémoire phonologique, de dénomination rapide automatisée alphanumérique et non alphanumérique à 6 et 7 ans et d'écriture de mots à 7 ans. Des analyses descriptives-exploratoires, des analyses bivariées et des régressions multivariées ont été modélisées. En général, les résultats montrent une contribution différente pour les variables cognitives considérées dans l'écriture de mots à l'âge de sept ans, bien que cette contribution ne varie pas sensiblement entre les âges de 6 et 7 ans chez les élèves espagnols. Les connaissances phonologiques à 6 et 7 ans sont la variable qui prédit le mieux l'écriture des mots à 7 ans. La contribution de la dénomination rapide non alphanumérique reste constante et la dénomination rapide alphanumérique ne contribue pas à l'explication de l'écriture à cet âge. La mémoire phonologique à 6 ans contribue à l'explication de l'écriture à 7 ans et la connaissance des lettres à 7 ans. Ces résultats ont des implications pour la pratique pédagogique et pour la théorie de l'acquisition de l'écriture dans les langues transparentes.

Resumen
El interés por los precursores cognitivos de la alfabetización ha ido en aumento en los últimos años, debido a que la lectura y la escritura son componentes esenciales de los aprendizajes funcionales en los primeros años de escolarización y del éxito escolar en etapas educativas posteriores. Sin embargo, se puede observar que mientras los estudios sobre la relación de variables cognitivas con la lectura son frecuentes los realizados con la escritura son más escasos, en distintas lenguas y edades. El objetivo de este estudio es conocer la contribución conjunta de determinadas variables cognitivas, medidas a los 6 y 7 años, en la escritura de palabras de niños españoles de segundo curso de Educación Primaria (7 años). En este estudio longitudinal, participaron 116 alumnos de habla española, pertenecientes a colegios de nivel sociocultural medio, sin necesidades educativas especiales. Los participantes fueron evaluados en conocimiento de las letras, conocimiento fonológico, memoria fonológica y denominación rápida alfanumérica y no alfanumérica a los 6 y 7 años y en escritura de palabras a los 7 años. Se realizaron análisis descriptivos-exploratorios, análisis bivariantes y se modelizaron regresiones multivariantes. En general, los resultados muestran diferente contribución de las variables cognitivas consideradas en la escritura de palabras a los siete años, aunque esta contribución no varía sustancialmente desde los 6 y los

7 años en estudiantes españoles. La variable que mejor predice a los 6 y 7 años la escritura de palabras a los 7 años es el conocimiento fonológico. La contribución de la denominación rápida no alfanumérica se mantiene constante y la denominación rápida alfanumérica no contribuye a la explicación de la escritura a esta edad. La memoria fonológica a los 6 años contribuye a la explicación de la escritura a los 7 años y el conocimiento de las letras contribuye a los 7 años. Estos resultados tienen implicaciones en la práctica educativa y en la teoría de la adquisición de la escritura en lenguas transparentes.

Introduction

Scientific interest in the cognitive precursors of early literacy has increased in recent years, because reading and writing are essential components of functional learning in the early years of schooling and school success in later educational stages (MEC, 2020). However, while studies on the relationship of cognitive variables to the acquisition of reading skills in different languages are well established (Asadi et al., 2017; Bar-Kochva & Nevo, 2019; Caravolas et al., 2013; Georgiou et al., 2012; González-Valenzuela et al., 2016; Torppa et al., 2019), research on the learning of writing has been scarce (González et al., 2015; Pinto et al., 2016; Suárez-Coalla et al., 2013; Vaessen & Blomert, 2013). One of the reasons for this situation is the variety of explanations about the association between reading and writing. In some cases, the existence of a two-way relationship between the two is postulated in which they share knowledge, cognitive systems, and communicative intentions (Ferroni et al., 2016; Fitzgerald & Shanahan, 2000; Kim et al., 2018). Advances in neuropsychology and neuroimaging studies indicate that the same neuronal circuits are activated in both processes (Gimenez et al., 2014; James et al., 2016; Vlachos, 2020). Other meta-analytical studies, on the other hand, suggest that reading proficiency accounts for up to 25% of writing performance, which in turn enhance and promote writing proficiency in the first few years of schooling (Graham et al., 2017; Kent & Wanzek, 2016). To some extent, there are also studies claiming that writing seems to influence reading at certain levels, suggesting that the relationships between some components of reading and writing may be asymmetrical (Kim el al., 2018; Malpique et al., 2020). This explains why writing is studied at the beginning of literacy. As a consequence, there has been an increase in research into writing, largely informed by reasons such as new methodological paradigms, which enhance and promote the cognitive processes involved in writing activities. This explains why there is the need to implement new teaching methodologies for writing, which in turn forge a relationship between reading, the writing process, and the inability to understand reading without writing and vice versa (De Bree & van der Boer, 2019; Georgiou et al., 2020; Nielsen & Juul, 2016; Ouellette & Senechal, 2017).

Most recent studies on the learning of writing analyse certain cognitive predictors, although not jointly in many cases, such as letter knowledge, phonological awareness, rapid automatised naming, and phonological memory (Aram et al., 2014; Babayigit & Stainthorp, 2011; Bar-Kochva & Nevo, 2019; Batnini & Uno,

2014; Binamé & Poncelet, 2016; De Bree & van der Boer, 2019; Furnes & Samuelsson, 2011; Georgiou et al., 2012; Georgiou et al., 2016; Harrison et al., 2016; Milburn et al., 2017; Moll et al., 2014; Nielsen & Juul, 2016; Ouellette & Senechal, 2017; Pinto et al., 2016; Pittas, 2018; Rothe et al., 2014; Vaessen & Blomert, 2013). These variables appear to correlate to a greater or lesser extent with writing, and their influence is modulated by the age or literacy of the students and by the linguistic complexity or consistency of the language (Bar-Kochva & Nevo, 2019; De Bree & van den Boer, 2019; Ferroni et al., 2016; Georgiou et al., 2012; Inoue et al., 2017; Juul et al., 2014; Pittas, 2018). In particular, more transparent and consistent languages such as Spanish, Italian, Finnish, or Norwegian have a finer grain structure, because graphemes more accurately represent phonemes, while more opaque or inconsistent languages such as English, Danish, or Chinese have a coarser grain structure, as graphemes less accurately represents phonemes. In addition, there are languages where this relationship depends on whether reading is more transparent than writing, such as Greek or German (Verhoeven & Perfetti, 2022). This might explain why the predictors of writing are different depending on the granularity of each language. In Spanish, so far, little research has explored the predictors of writing at an early age, and existing studies do not consider all these variables together (Ferroni et al., 2016; Gómez-Velázquez et al., 2010; González et al., 2015; Gutiérrez & Díez, 2018; Suárez-Coalla et al., 2013).

Knowledge of letters contributes to the explanation of word writing in consistent languages, since it favours phoneme-grapheme conversion in the writing process. But this relationship may vary according to the degree of orthographic consistency (Aram et al., 2014; Caravolas et al., 2012; Georgiou et al., 2012; Harrison et al., 2016; Juul et al., 2014; Milburn et al., 2017), which is one of the reasons for studying it in Spanish. Furthermore, knowledge of letters is one of the most significant predictors of writing skills in primary school children in other languages (Furnes & Samuelsson, 2011; Guo et al., 2018; Juul et al., 2014; Rowe & Wilson, 2015). Other studies indicate that the influence of letter knowledge is not limited to early stages of learning to write but continues to present positive and significant correlations with word writing at later stages of education, such as the third and fifth years of primary education (Batnini & Uno, 2014; Georgiou et al., 2016; Guo et al., 2018; Juul et al., 2014; Nielsen & Juul, 2016; Rowe & Wilson, 2015). In Spanish, studies tend to analyse more frequently the contribution of letter knowledge at an early age as an important predictor between the ages of five and six (Ferroni et al., 2016); nevertheless, the current studies do not consider this variable in combination with the other cognitive abilities that are proposed in this research.

Phonological awareness makes it easier to break words down into their phonemes and translate them into their corresponding graphemes in different transparent languages, making a relevant contribution to the explanation of word writing (Aram et al., 2014; Babayigit & Stainthorp, 2011; Biname & Poncelet, 2016; De Bree & van der Boer, 2019; Milburn et al., 2017; Moll et al., 2014; Nielsen & Juul, 2016; Pinto et al., 2016; Pittas, 2018; Vaessen & Blomert, 2013). Research evidence suggests that phonological awareness is a good predictor of writing words in Spanish at the beginning of the learning process, between the ages of 4 and 6 (Gutiérrez &

Diez, 2018; Suárez-Coalla et al., 2013). The study´s finding Ferroni et al. (2016) establishes that phonological awareness is relevant in writing at the beginning of schooling and how it ceases to be relevant from the second year of primary education, whereas the influence of orthographical processing on writing increases. Despite these findings, there are few studies in Spanish that can reinforce the results of this research in question, taking into account other cognitive variables such as those considered in this study.

Rapid automatised naming is a skill that integrates cognitive processes of a visual (detection and discrimination of visual traits) and phonological nature (integration of visual information with stored phonological patterns). It is evaluated by means of alphanumeric stimuli (letters and numbers) and non-alphanumeric stimuli (colours and objects) (Ferroni, et al., 2016; González-Valenzuela et al., 2022). Research on the relationship between rapid automatised naming and writing is not wholly conclusive, as different empirical measures are used for its study, such as the speed of identification for the first and accuracy of the response for the second (Savage et al., 2008; Suárez-Coalla et al., 2013). Furthermore, these stimuli are combined differently in tasks designed for research. Hence, some studies consider the naming of numbers, others the naming of objects and colours, and others separate alphanumeric stimuli from non-alphanumeric ones (González-Valenzuela et al., 2016). The dearth of research in Spanish on the role of rapid automatized naming in writing, in tandem with other cognitive variables to which it might be related, is one of the reasons for considering this variable within the context of age groups between 6 and 7 in Spanish.

Despite this, studies have been conducted in other languages, which establish that alphanumeric rapid automatised naming is a predictive variable for word writing in consistent languages (Bar-Kochva & Nevo, 2019; De Bree & van der Boer, 2019; Georgiou et al., 2016) and in more inconsistent or opaque languages (Babayigit & Stainthorp, 2011; Chen et al., 2021; Furnes & Samuelsson, 2011; Harrison et al., 2016; Inoue et al., 2017; Moll et al., 2014; Nielsen & Juul, 2016; Vaessen & Blomert, 2013) at different ages. Some theories suggest that the strong relationship between reading and writing seems to indicate that some variables influence each other in a similar way, such as alphanumeric rapid automatised naming, especially if the writing and reading are measured in terms of accuracy or precision (Chen et al., 2021). This potentially predictive variable provides quick access to representations and orthographic structures when writing certain irregular words. It also allows for quick connections to be made between phoneme and grapheme, and different types of information to be processed simultaneously (Altani et al., 2020).

Some studies also show the relationship of non-alphanumeric rapid automatised naming to word and pseudoword writing at early ages and when the learning of writing is already advanced, from the second and fourth years of primary education (Chen et al., 2021; Moll et al., 2014). This relationship is greater in the case of word writing in opaque languages, because it facilitates access to spelling patterns that do not follow a consistent phoneme and grapheme correspondence pattern. In addition, it has been shown that the neuronal networks active in the case of this variable are the same as semantic processing, which could facilitate the recognition of words by their meaning (Chen et al., 2021). In Spanish, it has been found that

non-alphanumeric rapid automatised naming correlates with word writing from the age of 7 (Ferroni et al., 2016; Gómez-Velázquez et al., 2010), but it does not correlate with writing at the age of 4 and 5. These discrepancies could be due to the fact that, at such early ages, non-alphanumeric rapid automatised naming, when considered with other variables relevant to writing, may not be so important (Rothe et al., 2014; Suárez-Coalla et al., 2013).

Another variable related to literacy learning is phonological memory, due to the participation of processes of organisation, planning, elaboration, coding and retrieval of phonological information (Lervag & Hulme, 2010). Phonological memory may play a more relevant role in writing than in reading, as repetition of phonemes is required in order to write them properly (Biname & Poncelet, 2016; Caravolas et al., 2012; Milburn et al., 2017; Niolaki et al., 2020; Suárez-Coalla et al., 2013). However, few studies have considered it. Some studies suggest that the role of phonological memory may be mediated by phonological awareness (Caravolas, et al., 2012; Harrison et al., 2016; Ouellette & Senechal, 2017; Zoccolotti et al., 2020). Other studies indicate that phonological memory is a predictive factor for writing, independent of phonological awareness (Biname & Poncelet, 2016; Chalmers & Freeman, 2018; Nielsen & Juul, 2016; Niolaki et al., 2020; Wealer et al., 2022). These skills may be more relevant in transparent and consistent languages, where the relationship between phoneme and grapheme is greater (Binamé & Poncelet, 2016; Chalmers & Freeman, 2018). In addition, the role of phonological memory would be more relevant at the early stages of learning to write, where verbal information is essential, but its effect would be reduced as schooling progresses in favour of other variables more closely related to orthographic processing (Nielsen & Juul, 2016). When it is operationalised as verbal memory, and sequence memorisation tasks are used, the relationship extends to higher school years (Chalmers & Freeman, 2018; Wealer et al., 2022). In Spanish, phonological memory has been studied at an early age as a phonological component, together with phonological awareness, but not independently, which does not provide us with information about whether this variable is relevant in writing between the ages of 4 and 5 or the extent to which it is relevant with respect to the other phonological components considered (Suárez-Coalla et al., 2013).

Therefore, due to the scarcity of research and controversy over the results found in other studies on the predictors of writing, the objective of this study is to explore the predictive capacity of the variables knowledge of letters, phonological awareness, phonological memory, and rapid automatised naming (alphanumeric and non-alphanumeric) at the age of six and seven in the writing of words by Spanish-speaking children at the age of seven.

Method

Participants

Based on the official list of school of the Ministry of Education (Consejería de Educación de la Junta de Andalucía, 2013), two schools were selected by means

of stratified random sampling to form the study sample (González-Valenzuela et al., 2022). From these two schools, initially, 116 Spanish speaking primary school pupils took part: 63 boys (54.3%) and 53 girls (45.7%) aged 6 years and six months old ($M = 79.74$ months, $SD = 3.47$). These same children participated in their second year of Primary Education.

As in previous studies (González-Valenzuela et al., 2022), 17% ($n = 19$) of the fathers and 6% ($n = 7$) of the mothers had a primary level of education; 65% ($n = 76$) of the fathers and 63% ($n = 73$) of the mothers had a secondary level of education (secondary education, high school, or vocational training); and 18% ($n = 21$) of fathers and 31% ($n = 36$) of mothers had a higher education (degree and post-graduate).

The participating pupils had no intellectual disabilities, no physical or sensory handicaps, and were fluent in the Spanish language, according to psychological reports compiled by the psychologists of the relevant schools. Pupils from foreign countries who were not fluent in Spanish were not considered.

Instruments

Word Writing (WWr) was evaluated using the Word Writing exercise included in the LEE Spanish Reading and Writing Test (Defior et al., 2006). The test evaluates the phonological and orthographic knowledge manifested when children from six to nine years of age write a dictation of words of different complexity and length (monosyllables, two-syllables and three-syllables), presenting good reliability and validity. It consists of writing a list of forty-four words that are dictated by the examiner. The responses of the subjects for each item are scored with a zero if they contain an error, and with one point if they are written correctly. The total score for each subject is the sum of the scores achieved on each item. The score range for this test is 0 to 44 points. The internal consistency reliability for the word writing test in the second year of primary school using Cronbach's alpha statistic is $\alpha = 0.84$. Test–retest reliability was shown with a correlation of 0.82. The study of convergent validity also yielded satisfactory indicators, with positive and significant correlations ($r = 0.59$, $P < 0.01$) found with the PROESC word writing test (Cuetos et al., 2004).

Knowledge of Letters (KL) was evaluated by means of the Letter Reading exercise included in the LEE test (Defior et al., 2006), which measures knowledge of all the letters in Spanish. It consists of naming the 29 letters of the Spanish alphabet. The total score is obtained from the sum total of letters correctly named. Internal consistency of this test, according to Cronbach's alpha statistic, is 0.60 and 0.64 for the first and second years of primary school, respectively. Test–retest reliability indicated a correlation of 0.50 and showed positive correlations with the word-reading and word-writing tests of the PROLEC battery (Cuetos, 2010) and the PROESC battery (Cuetos et al., 2004) between 0.15 and 0.20.

Phonological Awareness (PA) was evaluated by means of the phonemic segmentation exercise included in the LEE test (Defior et al., 2006), which consists of isolating the sounds or letters that make up 14 words, naming the phonemes or the letters they comprise. The total score achieved is the sum of correctly segmented

words. Cronbach's alpha statistic indicates an internal consistency of 0.91 and 0.86 for the first and second years, respectively, and test–retest reliability indicated a correlation of 0.64.

Rapid Automatised Naming (RAN) was evaluated by means of the RAN test (Wolf & Denckla, 2003) adapted by Gómez-Velázquez et al. (2010), which consists of naming 200 visual stimuli (50 letters, 50 numbers, 50 objects and 50 colours). As in González-Valenzuela et al. (2016), two measures have been considered in this variable: Rapid automatised naming of alphanumeric stimuli (AN-RAN) and rapid automatised naming of non-alphanumeric stimuli (NAN-RAN). The total score achieved by each subject is the time taken to name the alphanumeric and non-alphanumeric items. The internal consistency of the alphanumeric and non-alphanumeric items calculated using Cronbach's alpha was $\alpha = 0.58$ and $\alpha = 0.65$ for first year, and $\alpha = 0.59$ and $\alpha = 0.68$ for second year, respectively.

Phonological memory (PM) was evaluated using the Phonological Short-Term Memory (PSTM) test developed by Soriano and Miranda (2010), based on the Hebrew phonological memory task (Geva et al., 2000). It consists of repeating out loud a list of Latin words spoken by the examiner. These words are not related to the Spanish lexicon, not similar to Spanish morphology, and of varying length. The total score achieved by each subject is the number of words repeated correctly. Cronbach's alpha statistic for this test and sample was 0.57 and 0.63, for the first and second years, respectively.

Procedure

Once the relevant authority figures from the participating schools had signed the informed consent forms, approval was gained from the University of Malaga's Experimentation Ethics Committee (CEUMA).

The different tests described were administered by a group of psychologists. The variables knowledge of letters, phonological awareness, rapid automatised naming, and phonological memory were evaluated when the children were in the first year of primary education (6 years old). Later, when they were in the second year of primary education (7 years), they were evaluated for word writing and also for all these variables.

Each assessment was conducted individually over two sessions (approximately thirty minutes each). In the first year, when the pupils were six years old, the knowledge of letters and phonological awareness tests were administered first, followed by the rapid automatised naming (alphanumeric and non-alphanumeric) and phonological memory tests. In the second year, when the pupils were seven years old, word writing tests were administered first, followed by letter knowledge, phonological awareness, rapid automatised naming (alphanumeric and non-alphanumeric), and phonological memory tests.

Table 1 Descriptive statistics and correlations between word writing and cognitive variables measured at six and seven years old

Variables	Mean	SD	Range	1	2	3	4	5	6	7	8	9	10
1. LK	25.98	2.42	18–29	–									
2. PA	8.34	2.69	1–14	.37**	–								
3. PM	16.43	2.40	10–20	.19*	.27**	–							
4. AN-RAN	74.17	14.60	45–126	− .03	− .09	.08	–						
5. NAN-RAN	179.37	41.43	91–333	− .21*	− .17	− .18	.30**	–					
Seven years													
6. LK	27.01	1.50	22–29	.56**	.30**	.25**	− .02	− .08	–				
7. PA	10.15	2.39	1–14	.45**	.48**	.22*	− .17	− .31**	.34**	–			
8. PM	16.76	2.33	8–20	.11	.03	.33**	.10	− .10	.19*	.03	–		
9. AN-RAN	62.79	12.73	42–103	− .16	− .13	.09	.58**	.33**	.02	− .21*	− .01	–	
10. NAN-RAN	154.11	37.17	89–290	− .25**	− .17	− .09	.21*	.65**	− .05	− .29**	− .02	.35**	–
11. WW	33.81	4.07	23–43	.34**	.41**	.39**	− .08	− .31**	.38**	.46**	.21*	− .08	− .30**

**Pearson *r* correlation coefficient significant at $P < .01$; * Pearson *r* correlation coefficient significant at $P < .05$

Cohen's reference values correlation coefficient *r* effect size: small =|.10|; moderate =|.30|; strong =|.50| or greater

SD standard deviation, *LK* letter knowledge (n◦ of correct responses), *PA* phonological awareness (n◦ of correct responses), *PM* phonological memory (n◦ of correct responses), *AN-RAN* alphanumeric rapid naming (seconds), *NAN-RAN* non-alphanumeric rapid naming (seconds), *WW* word writing (n◦ of correct responses)

Table 2 Regressions analysis results for words writing at seven years from cognitive variables at six years old

	B	*SE B*	β	*t*	*p*	*sr*	VIF
Six years predictors							
Constant	26.36	2.96		8.89	.000		
PA	0.45	0.12	0.30	3.57	.001	.28	1.09
PM	0.45	0.14	0.27	3.19	.002	.25	1.10
NAN-RAN	− 0.02	0.01	− 0.21	− 2.60	.010	− .21	1.05
Goodness-of-fit tests							
F	15.31**						
R^2	.29						
Adjusted R^2	.27						
R	.54						

PA phonological awareness, *PM* phonological memory, *NAN-RAN* non-alphanumeric rapid naming, *SE* standard error, *sr* semi-partial correlation (unique), *VIF* variance inflation factor

Table 3 Regressions analysis results for words writing at seven years old

	B	*SE B*	β	*t*	*p*	*sr*	VIF
Seven years predictors							
Constant	12.53	5.99		2.09	.039		
PA	0.54	0.15	0.32	3.64	.000	.29	1.23
LK	0.71	0.22	0.26	3.13	.002	.24	1.13
NAN-RAN	− 0.02	0.01	− 0.20	− 2.40	.018	− .19	1.09
Goodness-of-fit tests							
F	16.51**						
R^2	.31						
Adjusted R^2	.29						
R	.55						

**Fisher's *F* test significant at $P < .01$

PA phonological awareness, *LK* letter knowledge, *NAN-RAN* non-alphanumeric rapid naming, *SE* standard error, *sr* semi-partial correlation (unique), *VIF* variance inflation factor

Statistical Analyses

Statistical analysis was carried out in two phases: firstly, a preliminary analysis was conducted out to later two model multivariate linear regressions. In the first phase, exploratory, descriptive and bivariate analyses were carried out. Once the parametric assumptions of normality, homoscedasticity and linear relationship between the variables were verified, for the bivariate analyses the Pearson correlation coefficients and their corresponding significance tests between all variables, measured at both six and seven years. A level of statistical significance was established at $P < 0.05$.

Effect size was considered small, moderate or strong, r=|.10|, r=|.30|, r=|.50| or greater, respectively, according to Cohen's criterion (1992).

In the second phase, Multivariate regressions models were then constructed to fulfil the primary objective of this study, respectively. Cognitive variables at six and seven years of age were identified that predict the written accuracy of words aged seven years. The joint and unique contribution of each variable was also calculated, in each regression model.

The models were built by introducing the independent variables sequentially., in decreasing order according to their corresponding correlation coefficient when in previous bivariate analyses they had an associated probability of less than 0.05 and an effect size equal to or greater than |.20|. To evaluate the overall significance of the estimated regression models and their parameters, Fisher's F test and Student's t test (two-tailed) were used, respectively. The coefficient of determination (R^2) and the adjusted coefficient of determination (Adjusted R^2) were used to assess overall the variance of written word accuracy attributable to the set of predictors included. The specific contribution of each predictor to the total variance of written word accuracy was calculated using the semi-partial correlation coefficient (sr_i^2). Assumptions of linearity, normality, and homogeneity of variances were verified a priori through the analysis of residuals. The variance inflation factor (VIF) was used to test the assumption of multicollinearity; values higher than 10 would indicate a high degree of multicollinearity.

Statistical data processing and analysis was carried out using version 28.0 of the Statistical Package for the Social Sciences (SPSS) (IBM, 2021).

Results

The statistical description of all variables and the bivariate correlations between all cognitive measures and the written accuracy of words are summarised in Table 1, showing that most of them were statistically significant.

Between the cognitive variables measured at six years of age, in the first year of primary, and the written accuracy of words measured at seven years of age, in the second year of primary, the statistically significant correlations found in decreasing order according to the size of the correlation were with phonological awareness (r=0.41, P<0.01), phonological memory (r=0.39, P<0.01), knowledge of letters (r=0.34, P<0.01) and non-alphanumeric rapid naming (r=− 0.31, P<0.01). However, no significant relationship was found with alphanumeric rapid naming (r=− 0.08, P=0.40).

At the age of seven, a relationship was found between phonological awareness (r=0.46, P<0.01), knowledge of letters (r=0.38, P<0.01), and non-alphanumeric rapid automatised naming (r=− 0.30, P<0.01), phonological memory (r=0.21, P<0.05) and written word accuracy. Again, with alphanumeric rapid naming, no statistically significant relationship was found (r=− 0.08, P=0.38).

The results obtained from the regression analyses at six and seven years old are summarised in Tables 2 and 3, respectively.

First, we studied which cognitive abilities at age six predicted written word accuracy measured at the age of seven. The final adjusted model [$F(3, 112) = 15.31$, $P < 0.001$], included the variables phonological awareness [$t(115) = 3.57$, $P < 0.01$], phonological memory [$t(115) = 3.19$, $P < 0.01$] and non-alphanumeric rapid automatised naming [$t(115) = -2.60$, $P < 0.05$], explaining 29% (27% adjusted) of the variance of the response variable written word accuracy at the age of seven ($R^2 = 0.0.29$). The corresponding semi-partial correlation coefficients (sr_i^2) indicated that these three initial cognitive variables contributed, respectively, 7.84%, 6.25%, and 4.41%, to the total variance of written word accuracy when the pupils were seven years old and in the second year of primary school (see Table 2).

Secondly, we examined which cognitive skills at the age of seven predicted written word accuracy measured at the same age (see Table 3). The final estimated model [$F(3,112) = 16.51$, $P < 0.001$], included the cognitive variables phonological awareness [$t(115) = 3.64$, $P < 0.001$], knowledge of letters [$t(115) = 3.13$, $P < 0.01$] and non-alphanumeric rapid automatised naming [$t(115) = -2.40$, $P < 0.05$]. The coefficient of determination ($R^2 = 0.31$) indicated that these variables as a whole explained 31% (29% adjusted) of the variability of written word accuracy, measured in the second year of primary school. The corresponding semi-partial correlation coefficients (sr_i^2) indicated that the unique contribution of the first one was 8.41%, the second was 6.25% and the third was 3.61%.

Analysis of residuals and the VIF verified that all the final estimated models fit the assumptions of linear regression.

Discussion

The objective of this study is to ascertain the impact made by knowledge of letters, phonological awareness, phonological memory, and alphanumeric and non-alphanumeric rapid automatised naming at the ages of six and seven years on the ability of Spanish children to write words at 7 years of age.

The results of this study establish that the cognitive variables measured at six years of age that predict word writing at age seven are phonological awareness, phonological memory, and non-alphanumeric rapid automatised naming. Alphanumeric rapid automatised naming and knowledge of letters were not part of the estimated final regression model. The cognitive variables measured at seven years of age that contribute to the explanation of written word accuracy at this age are phonological awareness, knowledge of letters, and non-alphanumeric rapid automatised naming. Neither alphanumeric rapid automatised naming nor phonological memory were part of the estimated final regression model.

Therefore, the contribution of cognitive variables considered in word writing at seven years of age does not vary substantially between the ages of 6 and 7. Phonological awareness is the best predictor at the ages of 6 and 7. The contribution of the non-alphanumeric rapid automatised naming at 6 and 7 years of age is constant, and alphanumeric rapid automatised naming does not contribute to the explanation of writing at these ages. Phonological memory at the age of 6 contributes to the

explanation of writing at age 7, and knowledge of letters at the age of 7 contributes to its explanation at this age.

As for the contribution of phonological awareness to the writing of words at the age of 7 in Spanish, the results found are in line with those of other studies carried out at early ages in different transparent languages, such as Finnish (Moll et al., 2014) and Norwegian (Lervag & Hulme, 2010), French (Biname & Poncelet, 2016), Swedish (Furnes & Samuelsson, 2011), German (De Bree & van der Boer, 2019; Rothe et al., 2014; Wealer et al., 2022) and Danish (Nielsen & Juul, 2016), and in less consistent languages such as English (Malpique et al., 2020; Milburn et al., 2017), Arabic (Batnini & Uno, 2014; Taha & Saiegh, 2016) or non-alphabetical Eastern languages (Inoue et al., 2017; Park & Uno, 2015). They are also in line with the results found in studies conducted with older subjects (Ferroni et al., 2016; Furnes & Samuelsson, 2011; Harrison et al., 2016; Nielsen & Juul, 2016). However, other research found no predictive relationship between phonological awareness in the early stages and writing in transparent languages at later ages (Bar-Kochva & Nevo, 2019; Georgiou et al., 2012). This could be due to disparity in ways of measuring phonological awareness used in the different studies, where in some cases certain types of syllable-based tasks are used and in other cases different phoneme-based tasks are used. It could also be due to the effect of other variables with which it has been considered jointly (Gutierrez & Diez, 2018; Pittas, 2018). It should be noted, however, that the results of our study agree with other studies conducted in Spanish that identify significant associations between phonological awareness and word writing in children evaluated at early ages (Gutierrez & Diez, 2018; Suárez-Coalla et al., 2013). Our results indicate that phonological awareness continues to be, from six years to seven years of age, a strong predictor of written word accuracy in Spanish, since it makes it possible to carry out phoneme-grapheme conversion.

With regard to the contribution of rapid automatised naming, the results of our study differ in some cases from those found in other studies. Disparity in the conditions under which rapid automatised naming and writing were studied may lead to different conclusions (de Bree & van der Boer, 2019; Georgiou et al., 2016), contrary to other studies (Moll et al., 2014; Niolaki et al., 2020; Vaessen & Blomert, 2013; Zoccolotti et al., 2020).

With regard to the contribution of non-alphanumeric rapid automatised naming, our results do not coincide with those achieved at an early age (Niolaki et al., 2020; Suárez-Coalla et al., 2013; Zoccolotti et al., 2020), but they do concur with those found in other research conducted with first and second year primary school pupils in different transparent languages (Bar-Kochva & Nevo, 2019; Ferroni et al., 2016; Furnes & Samuelsson, 2011). In addition, its influence can be discerned in later years, with significant correlations found between non-alphanumeric rapid automatised naming and writing after controlling for other cognitive variables such as phonological awareness (Georgiou et al., 2012; Lervag & Hulme, 2010; Moll et al., 2014; Nielsen & Juul, 2016).

Furthermore, our results are in line with some studies that consider that alphanumeric rapid naming to be more closely related to no early stages of learning writing, since it would be more closely related to orthographic knowledge and the learning of writing in less consistent languages (Chen et al., 2021; Harrison et al., 2016; Inoue

et al., 2017; Vaessen & Blomert, 2013) and not so much with the initial stages of learning to write and phoneme-grapheme conversion. Along these lines, in Spanish, it was found that alphanumeric rapid automatised naming correlates with the writing of words from the age of 7 (Ferroni et al., 2016; Gómez-Velázquez et al., 2010). These results could be due to the fact that alphanumeric rapid automatised naming is a measure of speed, and writing is based on accuracy criteria, as other studies have considered. There is also disparity in the way rapid automatised naming is measured that makes it difficult to interpret and generalise results (Bar-Kochva & Nevo, 2019; De Bree & van der Boer, 2019).

As for the relationship between phonological memory and writing at the age of seven in Spanish, our results coincide with those of studies conducted at earlier ages (four-five years old), which also considered it together with other phonological variables, such as phonological awareness (Suárez-Coalla et al., 2013). Both variables seem necessary in the phoneme-grapheme conversion process carried out in Spanish word writing even at younger ages (Harrison et al., 2016; Suárez-Coalla et al., 2013), and it appeared that the relevance of phonological memory could be mediated by phonological awareness (Caravolas et al., 2012; Ouellette & Senechal, 2017), in contrast to the indications of other studies (Binamé & Poncelet, 2016; Chalmers & Freeman, 2018). However, we did not find that this variable was associated with word writing at seven years of age, and our results did not coincide with other studies that point to significant correlations between verbal memory and word writing, improving writing skills months after having received reading instruction. This influence is important once other cognitive variables are controlled (Babayigit & Stainthorp, 2011; Lervag & Hulme, 2010). These discrepancies could be due to the fact that these studies used word or digit memory tasks and not pseudowords, which is considered to be more short-term verbal memory than phonological memory (Binamé & Poncelet, 2016; Chalmers & Freeman, 2018). Furthermore, the fact that phonological memory contributes to the explanation of writing at 6 but not at 7 years of age could be due to the fact that at this age children are already literate, know the names and sounds of the letters, and when considered together with other variables, its contribution decreases.

As for the contribution made by knowledge of letters to Spanish writing at seven years of age, our results coincide with those found at early ages in different consistent languages (Aram et al., 2014; Guo et al., 2018; Juul et al., 2014; Milburn et al., 2017; Rowe & Wilson, 2015; Wealer et al., 2022) and in Spanish (Ferroni et al., 2016) and are in line with studies that argue that its influence is not limited to the beginning of learning to write, but also occurs at later ages (Graham et al., 2017; Guo et al., 2018; Juul et al., 2014; Milburn et al., 2017; Nielsen & Juul, 2016; Rowe & Wilson, 2015). It should be noted that knowledge of letters is crucial to phoneme-grapheme conversion in the process of writing words, even at slightly older ages. The fact that knowledge of letters does not contribute at six years of age to writing at seven years of age in our study could be because at the age of six the learning process of writing is not yet automated as it can be at 7. It would be advisable for future studies to analyse the evolution of the acquisition of writing in a longitudinal way, since it would provide relevant information when studying the determining factors.

In summary, this study shows the important influence that phonological awareness and non-alphanumeric rapid automatised naming have on the writing of words in Spanish at the age of seven from the age of six, while phonological memory and knowledge of letters show their influence at six and seven years old, respectively, and alphanumeric rapid automatised naming is not remarkable at this age. In general, the different variables considered (phonological awareness, knowledge of letters, phonological memory, alphanumeric and non-alphanumeric rapid automatised naming) do not have the same influence on the writing processes, presenting a different predictive character according to age, when considered together. Furthermore, it also suggests that predictors of writing do not have to be the same as those of reading, in the same language and at the same age (González-Valenzuela et al., 2022), going against other research that indicated that reading and writing share common predictors (Altani et al., 2020; Chen et al., 2021; De Bree & van der Boer, 2019; Georgiou et al., 2020; Malpique et al., 2020; Verhoeven & Perfetti, 2022). However, it seems that it may be consistent with studies that showed an asymmetrical relationship between reading and writing, although they are influenced jointly by the literacy process (Graham et al., 2017; Kent & Wanzek, 2016; Malpique et al., 2020).

In future studies, other cognitive variables should be considered that could modify the results found in this study at these ages, such as auditory perception, executive functions, morphological awareness, or vocabulary (Pittas, 2018; Taha & Saiegh, 2016), which have not been considered in this study. Writing speed, a variable that could influence performance and the contribution of the cognitive variables considered, has also not been considered in this study. It is important to mention the scarcity of existing studies when looking for relationships between some cognitive measures with writing compared to reading processes, indicating the need for further study of writing. We should also highlight how some variables are measured differently in many studies (for example, rapid automatised naming, phonological awareness, or phonological memory), which makes it difficult to advance the study of writing predictors. In addition, it would be important to consider the relationship of the cognitive predictive variables indicated in the learning of writing in less consistent languages, such as Arabic or Japanese, where phoneme-grapheme correspondence is not reciprocal, and the relevance of the cognitive processes studied may vary (Guo et al., 2018; Inoue et al., 2017; Moll et al., 2014; Taha & Saiegh, 2016).

The results achieved could have relevant educational implications, as it would be interesting to highlight new educational initiatives focused on the teaching of writing, such as influencing the amount of time spent teaching the rules of phoneme-grapheme correspondence, the development of guidelines that allow children to gain a firm grasp of spelling rules, and the amount of time the teacher devotes to these processes. We should also emphasise the importance of working on and promoting the development of different phonological skills in order to foster the learning of writing, even before compulsory literacy instruction, especially to improve, promote, and optimise teaching–learning processes in the early ages of writing acquisition, thus preventing the appearance of difficulties.

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose. The authors have no conflicts of interest to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or nonfinancial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

Informed Consent The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by Research Ethics Committee at the of the Universidad de Málaga (CEUMA) in order to initiate data collection. Permission was obtained after the headteachers of the participating schools signed the respective informed consent.

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