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Naming Abilities and Orthographic Recognition during Childhood an Event-Related Brain Potentials Study

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Abstract

Children with reading disabilities or dyslexia, commonly suffer disturbances in phonological awareness, slow-naming speed, and delayed automatic word recognition. A close relation between naming speed and reading difficulties has been well documented; hence, the former could be a useful early predictor of dyslexia. Reading disabled children usually show orthographic problems, but the neurophysiological basis underlying the detection of orthographic violations is still unclear. In this study, 28 healthy, right-handed, second-grade children were selected from a wider screening study and divided into two groups according to their performance on a rapid-naming test battery: slow-naming (SN) and average-naming (AN). Groups were matched by sex, age and school grade, and participants were asked to perform a visual recognition task that consisted of two stimuli: an easily-named drawing followed by a word that either matched (congruent) or did not match (on semantic or orthographic grounds) the drawing. Subjects were instructed to judge the relationship between each pair of stimuli and then press a key on a keyboard while ERP were being recorded. Behavioral results showed significant differences between groups in terms of the number of correct responses, but only for the orthographic violation condition, as no significant differences were observed in reaction times. In addition, SN showed poorer reading performance compared to AN. ERP were significantly different between the two groups during processing of visual words. Results are interpreted as the expression of the difficulties that SN manifested in generating strong associations between phonological and orthographic word forms.

Keywords: reading disabilities, naming speed, word recognition, orthographic processing, ERP, children

1. Introduction

There is agreement on the existence of a primary deficit in developmental dyslexia across languages that involves the neural representation of phonological structures in speech, and this notion has been well documented by several studies (Abrams, Nicol, Zecker, & Kraus, 2009; Bradley & Bryant, 1978; Denckla & Rudel, 1976; Meyler & Breznitz, 2005; Seki, Okada, Koeda, & Sadato, 2004; Wimmer, 1993). However, phonological deficits affect reading in different ways, depending on the orthography children must learn. Literacy problems are greater for dyslexic children who need to learn to read inconsistent orthographies (e.g., English) than for those who read consistent orthographies, such as Italian, German and Greek (Goswami, 2002).

Learning to read in Spanish seems to be less affected by phonological deficits, as previous reports on Spanish-speaking children have shown that reading speed is the core deficit manifested by dyslexics (Escribano, 2007; Serrano & Defior, 2008), while phonological deficits represent only a secondary problem.

Spanish is considered a language with regular orthography due to its high grapheme-phoneme correspondence. This regularity has an important effect on the speed at which children acquire reading skills: in regular orthographic systems such as Italian, German and Spanish, children typically reach optimal reading accuracy by the end of the first grade (Goswami, Gombert, & Fraca de Barrera, 1998; Landerl & Wimmer, 2008; Seymour, Aro, & Erskine, 2003), because learning of letter-sound associations proceeds rapidly. Goswami (2002) suggests that this might be because the mapping problem is less difficult: i.e., children have to learn to read consistent alphabetic orthographies with an open (consonant-vowel: CV) syllabic structure, where onset-rime segmentation is equivalent to phonemic segmentation (theoretically learned through literacy) for many words; in addition, one letter consistently maps to one phoneme. Though this is the case for reading in Spanish, writing is quite different, for some phonemes are mapped onto more than one letter and frequently result in the writing of pseudohomophones (words with an orthographic error but the same phonology as the correct one), or to recognition of a pseudohomophone as a valid word. Some of these phonemes are /s/, /b/, /y/, /j/, plus the grapheme *h,* which is silent. Words containing these graphemes are often miswritten by Spanish-speaking children.

Grapheme-phoneme recoding strategies develop rapidly and constitute a reliable strategy for children learning to read in Spanish, or other orthographies, such as German. The highly consistent grapheme-phoneme correspondences of these orthographies, together with the straightforward phonics-based teaching approach, allow even dyslexic children to acquire the process of phonological decoding (Landerl & Wimmer, 2008; Seymour, Aro, & Erskine, 2003; Landerl, 2001). The different potential solutions to the mapping problem suggest that children will develop distinct reading strategies in response to differences in orthographic structure across orthographies; distinct strategies that might underlie differences in the dyslexic symptoms observed in children who acquire reading skills in shallow or deep orthographic systems.

In general, weaker orthographic recognition skills have been reported in dyslexic children compared to matched controls (Friedmann & Lukov, 2008; King, Lombardino, & Ahmed, 2005; Lovett, Ransby, & Barron, 1998; Stanovich & West, 1979). Weak orthographic codes and related slow reading are core factors associated with a predictive variable: the speed in naming simple symbols. Bowers and Wolf (1993) hypothesized that slow letter- (or digit-) naming speed may signal a disruption of the automatic processes that support the induction of orthographic patterns that in turn allow fast word recognition. A longitudinal study of Spanish-speaking children showed that letter-naming speed is the best early predictor of reading performance, mainly for text-reading speed and orthographic writing. This supports the hypotheses of a failure to abstract orthographic regularities after repeated print exposure, and of difficulties in acquiring automatic word recognition by the third grade (Gómez-Velázquez, González-Garrido, Zarabozo, & Amano, 2010).

To the best of our knowledge, no studies have addressed the psychophysiology of automatic word recognition in the early stages of reading acquisition in children with slow letter-naming speed. Since they encounter difficulties in automatically recognizing the orthographic patterns of frequently used words, we can hypothesize that they will be less effective than controls in recognizing orthographic violations in words, especially pseudohomophones, which have been widely used to study the role of phonological, orthographic, semantic and syntactic information in visual word recognition processes (Münte, Heinze, Matzke, Wieringa, & Johannes, 1997; Newman & Connolly, 2004; Sauseng, Bergmann, & Wimmer, 2004; Vissers, Chwilla, & Kolk, 2006; Briesemeister et al., 2009; Braun, Hutzler, Ziegler, Dambacher & Jacobs, 2009).

Regarding the specific homophone effect, a brain activation pattern that includes the inferior frontal gyrus, the inferior parietal lobe and the superior temporal cortex has been described, though activation of the latter might be more closely related to the number of lexical alternatives (Newman, 2011). However, several factors must be considered when studying homophone effects during lexical decisions, including: the frequency of the homophone, the orthographic characteristics of non-word trials, the phonological nature of the non-words used, task demands, and reading and phonological skills (Holyk & Pexman, 2004; Pexman, Lupker, & Jared, 2001; Unsworth & Pexman, 2003), all of which not only underlie the homophone effect but might also be relevant to word recognition, which occurs in a very short lapse. Thus, it may be important to determine whether slow-naming children have difficulties in storing orthographic memory representations or in automatizing those representations when discriminating pseudohomophones from real words.

Due to the speed of the visual word recognition process, event-related potentials (ERP) have been widely used to evaluate its temporal course. In this regard, word length and early letter n-gram frequency affect ERP responses –from 90 to 100 ms after word-onset– (Hauk, Davis, Ford, Pulvermüller, & Marslen-Wilson, 2005; Hauk, Pulvermüller, Ford, Marslen-Wilson, & Davis, 2009). Lexical frequency influences ERP at 110 ms, while word-pseudoword difference effects have been described near 160 ms after word-onset (Hauk, Davis, Ford, Pulvermüller, & Marslen-Wilson, 2005). In Spanish, masked priming experiments suggest that priming orthographic ERP effects occur between 150 and 250 ms, whereas phonological priming seems to take place in the 350-550 ms latency window (Carreiras, Perea, Vergara, & Pollatsek, 2009).

It has been stated that there is an occipito-temporal brain sensitivity (reflected by ERP effects earlier than 250 ms) during the earliest phase of reading acquisition that accompanies the basic associative learning of letter-speech sound correspondences in young, non-reading, kindergarten children (Brem et al., 2010). Recently, while studying lexical decision processes in slow-naming 7-to-8-year-old children attending regular elementary schools, we described a negative ERP component that peaked at 320 ms and correlated significantly with performance on a letter-naming task, reading speed and reading comprehension (González-Garrido, Gómez-Velázquez, Zarabozo, Ruiz-Villeda & de la Serna Tuya, 2011). These findings suggest that the N320 component is sensitive to orthographic processing, and thus support the hypothesis which postulates that the processes underlying slow-naming speed may contribute to reading failure, probably by limiting the quality of the orthographic codes held in memory, and/or by impeding the appropriate linking between phonemes and orthographic patterns at the sub-word and word levels of representation. Briefly, the failure to sufficiently automatize letter recognition interferes with letter string processing and the development of orthographic knowledge (Bowers, Sunseth, & Golden, 1999).

In light of such earlier results, the main aim of the present study was to evaluate the ERP waveforms in slow-naming and control children during performance of an orthographic recognition task in which each word to be evaluated could be elicited mentally by the previous appearance of a matching easily-named drawing.

2. Method

2.1 Subjects

28 native Spanish-speaking children that showed a right-handed preference in all items explored (Annett, 1970) were selected from a pool of 121 children from one regular elementary school, according to their performance on four naming tasks (drawings, letters, numbers and colours), and then divided into two groups: Average-naming (AN) with 14 8-year-old children (9 male) who achieved average naming times on the four tasks (performance difference less than one SD from the total averaged sample for naming times in each task); and Slow-naming (SN) also with 14 8-year-old children (9 male), but whose naming times were slower by 1.5 standard deviations (SD) on the letter-naming task (see Table 1).

Table 1. Naming and reading performances of average- and slow-naming children

NAMING TASKS	AVERAGE NAMING	SLOW NAMING		
	Mean (SD)	*Mean (SD)*	*Student´s (t)*	*p(t) value*
Drawings	1:12 (0:19)	1:31 (0:39)	-1.606	0.125
Letters	0.38 (0:06)	1:09 (0:18)	-5.746	**0.000**
Numbers	0:29 (0:03)	0:31 (0:06)	-1.025	0.317
Colors	0:59 (0:10)	1:05 (0:16)	-1.102	0.283
Average (4 tasks)	3:19 (0:27)	4:15 (0:59)	-3.228	**0.003**
READING TASKS				
Reading speed (words per minute)	75.6 (15.3)	42.1 (14.1)	6.015	**0.000**
Misread words in the text	3.1 (2.7)	11.7 (7.2)	-4.181	**0.000**
Text comprehension	16.3 (3.4)	11.4 (4.2)	3.429	**0.002**

SD: standard deviation. Naming times are presented in minutes and seconds

The two groups were matched according to age, handedness, gender, educational level, and full-scale IQ score. All had a Wechsler Intelligence Scale (Wechsler, 1984) global IQ of 90 or higher, and were studying the second grade in a normal primary school. They had no personal or family history of psychiatric, neurological or degenerative illness, nor had they been diagnosed with ADHD, or with any emotional disturbance or behavioural disorder, according to DSM-IV criteria. Children were excluded if they were known to have speech or articulatory problems. All children underwent a neurological examination and a baseline EEG with normal results.

Seventeen of the children met the criteria to be considered as slow letter-naming subjects, but the electrophysiological data for three of them had to be discarded due to an excessive number of ERP artifacts.

Neuropsychological evaluation of SN and AN children revealed no significant differences between the groups during performance of tasks that involved primarily attentional capabilities (i.e., the continuous performance test and the dual attention task).

In addition, subjects in SN and AN were asked to read aloud a short narrative text consisting of 218 words in order to measure the following parameters: a) reading speed; b) number of misread words; and, c) text comprehension. See Table 1.

Pearson correlations demonstrated that the time employed to perform the letter-naming task significantly correlated with reading speed –*i.e.*, number of words read per minute– ($r = -0.616$; $p<0.01$), with slower-naming children tending to read fewer words per minute.

2.2 Experimental Task

A classic delayed matching-two-samples paradigm was used to design an experimental task in which participants had to make orthographic and semantic decisions. Each trial consisted in the sequential presentation of an easily-named drawing from one of three counterbalanced categories (object, fruit, animal) shown for 1500 ms on a 14" CRT monitor (Screen Resolution/Refresh Rate**:** 800x600/60Hz), followed by a two- or three-syllable word that either corresponded (congruent: CO) or did not (incongruent due to a semantic, SI, or orthographic, OI, mismatch) to the drawing. The latter stimuli (word) also lasted 1500 ms with an ISI of 1000 ms. Subjects were instructed to determine whether or not the word corresponded to the drawing by pressing, as fast as possible, a keyboard key with their left or right index fingers, respectively. The key order was counterbalanced across conditions and subjects.

2.3 Stimuli

A total of 186 frequent, familiar, concrete two- or three-syllable words (no synonyms) were obtained from textbooks used at the 1st and 2nd elementary school levels. The words were divided into three lists (62 words each) and then dictated to 120 8-year-old children attending a different school than that of the experimental children (40 children per list). Pseudohomophone errors (pseudowords phonetically identical to a word) were analyzed, and it turned out that 59 pseudohomophone errors were written by 5 or more children.

Also, 160 drawings that matched the selected words were made and digitalized. The images were in black & white (250 x 162 pixels) at 640 x 480 dpi resolution. Ten subjects who satisfied the inclusion criteria then participated in a pilot study designed to evaluate drawing recognition and naming.

Of those drawings, 138 were well recognized visually, and named correctly in the pilot study, so 92 corresponding pairs (drawing-word) were arranged. Forty-six pairs were kept alike (CO), while those in the other 46 pairs (OI) were replaced by pseudohomophones (the ones most often written by the aforementioned pilot group; e.g., GALLO x GAYO (*i.e.* laser x lazer).

In order to explore an equivalent condition while representing semantic mismatches, 48 additional drawing-word pairs were constructed (SI) using the remaining drawings, followed by a two- or three-syllable word that was a frequent sample from a different semantic category –e.g., the image of a hammer followed by the word "CAT".

2.4 Phonological Characteristics of the Words Used as Stimuli

The words used as stimuli shared the following characteristics: an average of 2.3 (SD: 0.49) syllables; an average of 1.22 (SD: 1.13) phonological obstacles; a consonant ending one syllable followed by another consonant that began the subsequent one; two vowels within a syllable, or one preceding and another starting a syllable; or two consonants that began the syllable or formed part of the closing syllable. All these conditions were considered phonological obstacles (Leal & Suro, 2006). There were no significant differences in the number of syllables or phonological obstacles between conditions.

2.5 Procedure

Subjects were tested in a sound-attenuated room. The words used as stimuli appeared in white capital letters against a black background subtending a visual angle of 0.75^0. The list with all the drawing-word pairs from the 3 experimental conditions (CO, SI and OI) was semi-randomized and divided into 2 blocks to be administered with a brief rest period between them. The presentation order of the blocks was appropriately counterbalanced among subjects, who were instructed to minimize eye and body movements during the experiment. All children were adequately trained before performing the task.

Stimulus delivery, response collection and data acquisition onset were all synchronized and controlled by the MINDTRACER software (2003).

2.6 Electrophysiological Methods

2.6.1 Recording

Electroencephalographic activity was recorded at the Fp1, Fp2, F3, F4, F7, F8, C3, C4, P3, P4, O1, O2, T3, T4, T5, T6, Fz, Cz and Pz scalp sites. Electrooculograms (EOG) were recorded at the outer canthus and infraocular orbital ridge of the right eye. Electrophysiological recordings were done using 10 mm diameter gold disk electrodes (Grass Type E5GH) and Grass electrode cream. All recording sites were referred to linked mastoids. Inter-electrode impedances were below 5 kΩ at 30 Hz. EEG and EOG signals were amplified at a bandpass of 0.5-30 Hz (3-dB cutoff points of 6 dB/octave rolloff curves) with a sampling period of 4 ms on the MEDICID-03E system. Data was collected as 1.100-s epochs for all recording channels beginning 100 ms prior to stimulus onset. Single trial data were stored off-line for averaging and analysis.

2.7 Data Analysis

2.7.1 Behavioral Measures

Correct and incorrect responses were automatically marked on the EEG by the software. In addition, reaction times were recorded simultaneously.

2.7.2 Signal Averaging

Epochs of data on all channels were excluded from averages when the voltage in a given recording epoch exceeded 100 µV on any EEG or EOG channel. Additional epochs with artifacts were rejected by visual inspection. Fifteen artifact-free correct trials were considered to obtain the individual ERP in each condition. Each individual ERP reached a standard deviation rate (SDR) below 1.1 and a residual noise level (RNL) below 2.

2.7.3 Statistical Analysis

Independent sample t-tests (including Bonferroni corrections) were applied to the behavioral data. According to the visual examination of the resulting group-averaged ERP waveforms, the main voltage variations were estimated in order to examine the electrophysiological data in several time windows. Randomized-block ANOVAs (Group x Condition x Recording Site) were conducted on maximum voltage peak values across each time window as the dependent variable. Greenhouse-Geisser corrections of *df* were applied as needed, with the corrected probabilities reported. Additionally, post-hoc Tukey's HSD tests were done to explore trends in the changes observed.

3. Results

3.1 Experimental Task Performance

AN showed a significantly higher number of correct responses than SN ($F_{1,26}$=9.69, $p<0.01$). Analysis also showed relevant differences between conditions ($F_{2,52}$=96.6, $p<0.001$) with a significant group x condition interaction effect ($F_{2,52}$=4.06, $p<0.05$). See Table 2. Post-hoc analyses demonstrated that a lower number of correct responses was achieved for Orthographic Incongruence than for Congruency ($p<0.01$), and Semantic Incongruence ($p<0.01$). In addition, post-hoc analyses of the interaction effect showed that SN had significantly fewer correct responses than AN only for Orthographic Incongruence ($p<0.01$).

The analysis of reaction times demonstrated significant differences for the factor Condition ($F_{2,52}$=22.87, $p<0.0001$), as both groups showed prolonged reaction times during OI [vs. CO($p<0.01$) and vs. SI($p<0.01$)]. No other significant differences or interaction effects were found.

Table 2. Behavioral results while performing the experimental task

CONDITIONS		AVERAGE NAMING	SLOW NAMING		
		Mean (SD)	*Mean (SD)*	*Student´s (t)*	*p(t) value*
Congruency	Correct	36.3 (4.4)	36.1 (5.9)	0.109	0.914
	Incorrect	7.5 (3.6)	7.6 (5.4)	-0.082	0.935
	No Responses	2.2 (2.2)	2.3 (3.1)	-0.069	0.945
	Reaction Time	1190.0 (149.2)	1195.1 (209.7)	-0.074	0.942
Orthographic Incongruence	Correct	**24.8 (7.5)**	**15.9 (7.7)**	**3.090**	**p<0.01**
	Incorrect	**18.5 (7.9)**	**27.2 (8.8)**	**-2.751**	**p<0.05**
	No Responses	2.7 (1.7)	2.9 (4.3)	-0.115	0.909
	Reaction Time	1345.9 (181.1)	1377.9 (229.2)	-0.411	0.685
Semantic Incongruence	Correct	42.6 (2.7)	40.1 (5.2)	1.607	0.120
	Incorrect	1.1 (0.9)	4.3 (4.7)	-2.020	0.054
	No Responses	2.3 (2.4)	2.4 (2.8)	-0.072	0.943
	Reaction Time	1137.9 (167.5)	1218.9 (220.7)	-1.094	0.284

SD: standard deviation.

Pearson's correlation analysis showed a significant negative correlation between letter-naming speed and the number of hits obtained in OI (r=-.530); that is, while detecting orthographic incongruence children with higher letter-naming times obtained a lower number of correct responses.

3.2 Electrophysiological Results

With respect to the visual examination of the group-averaged ERP waveforms and their variations in the 3 experimental conditions, 4 time windows were used to evaluate the electrophysiological data: W1:165-265; W2:320-420; W3:400-500 and W4:600-700 ms, respectively. The factor Recording Site was analysed at the midline locations Fz, Cz and Pz, where the main visually-detected changes took place.

3.3 Description of Event-Related Brain Potentials

Group averaged, event-related brain potentials in AN showed a typical sequence of components, P-N-P-N, which peaked at about 50, 170, 220 and 380 ms respectively. They were followed by a slow positive waveform that appeared to be divided into 2 different components in the parietal regions, and reached their maxima at approximately 480 and 640 ms. Both N380 and the subsequent positive component showed greater amplitudes in the incongruent conditions (OI & SI). The left side of Figure 1 shows the ERP obtained for the 3 experimental conditions in AN.

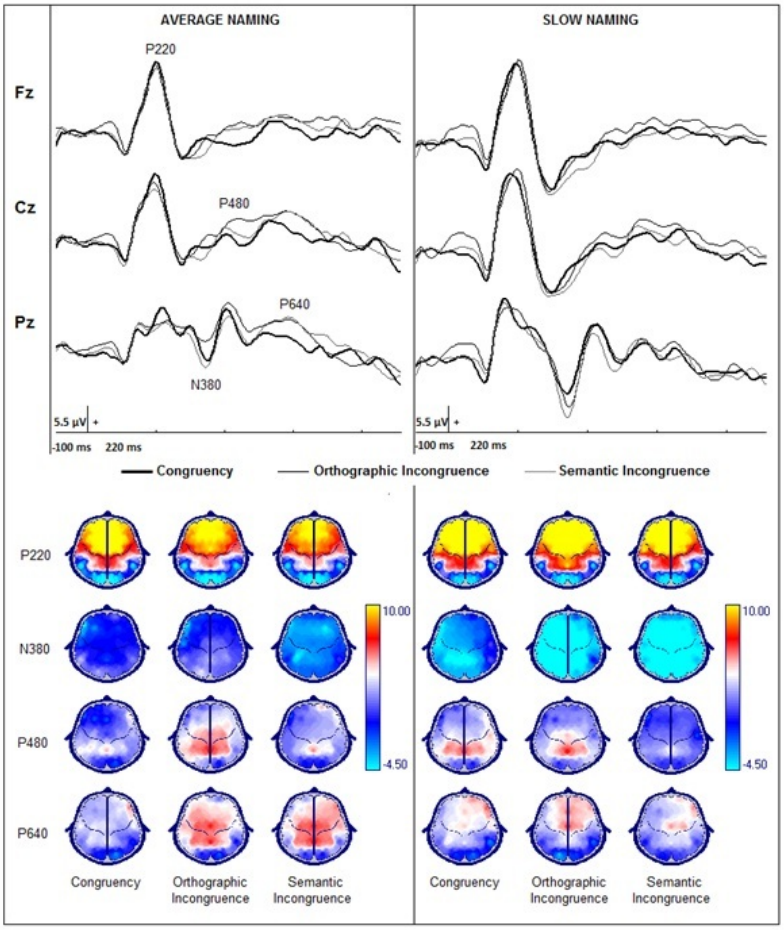

Figure 1. Midline grand mean waveforms of ERP during the experimental task in the Average-Naming group –left side– and Slow-Naming group –on the right

The ERP obtained from SN children showed greater amplitudes but similar morphology and latencies to those depicted for AN. Regarding visual inspection, voltage differences between experimental conditions appeared to be smaller in SN. The right side of Figure 1 shows the ERP components from this group.

Statistical analysis showed no significant effect for the first time window (W1:165-265 ms), but over the temporal areas, N170 showed a tendency towards greater bilateral distribution in AN than in SN, reaching its highest amplitude over the left hemisphere in the latter (see Figure 2). Although this effect was not statistically significant, likely due to individual variability, it could indicate slight early differences in visual processing expertise [40] between AN and SN groups of children.

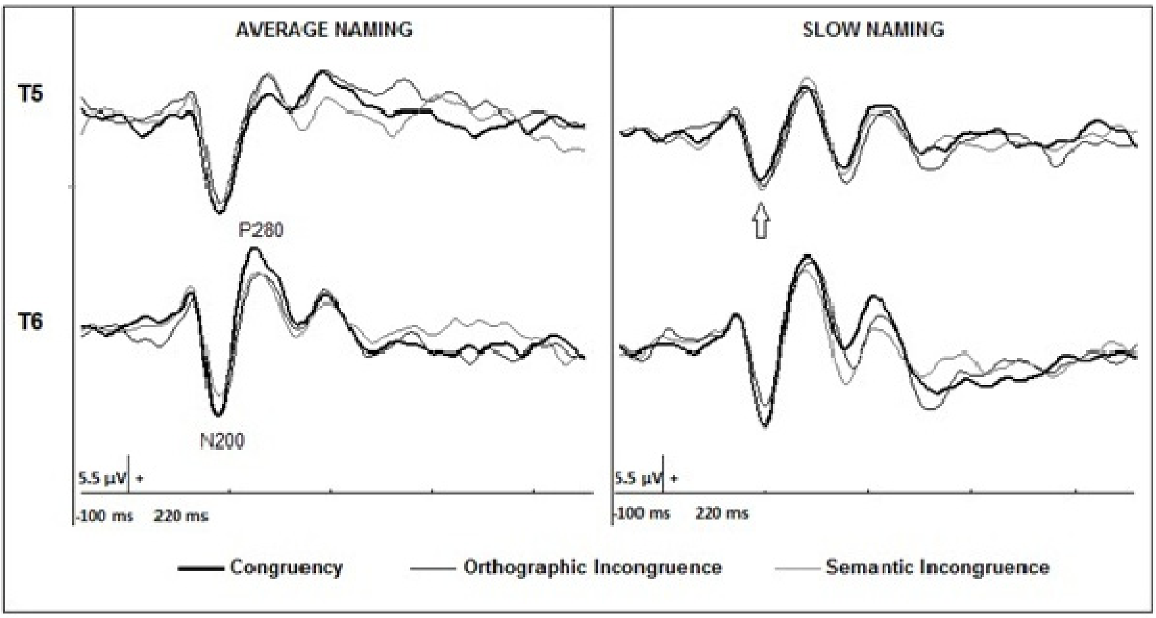

Figure 2. Grand mean waveforms of ERP in temporal areas during the experimental task in the Average-Naming group –left side– and the Slow-Naming group –on the right

In W2, which corresponded to the N380 component, there were significant differences for the factor Group ($F_{1,26}$=6.39, $p<0.05$), showing that N380 reached significantly lower voltage amplitudes in AN children compared to SN. However, no interaction effect reached statistical significance in this time frame.

In W3 –the period in which component P480 appeared– there were significant differences between groups ($F_{1,26}$=6.01, $p<0.05$) that corresponded to the higher voltage of P480 in AN, with a significant interaction effect between Group and Condition ($F_{2,52}$=4.68, $p<0.05$). Post-hoc analysis showed that the increase of the P480 voltage was significant only in OI ($p<0.01$). Finally, in W4 –late positivity– no significant effects were found, probably due to individual variability.

In summary, ERP results showed higher voltages for SN children in all conditions, especially those corresponding to orthographic or semantic incongruence. AN showed clear differences between the experimental conditions regarding the N380 component. In addition, AN showed a significantly higher positivity, with a peak at approximately 480 ms during OI, while subsequent positive waveforms (P640) showed higher voltages for the incongruent conditions (OI and SI) with respect to CO, though the latter effect did not reach statistical significance.

4. Discussion

The main aims of the present study were to evaluate the process in which an appearing word was compared to the mental representation elicited by the previous presentation of a drawing in average- and slow-naming children, and to test the hypothesis that slow letter-naming speed in Spanish could signal disruptions of the automatic processes that support induction of orthographic patterns, as proposed earlier by Bowers and Wolf (1993).

This specific kind of experimental task makes 2 demands on participants: detecting a semantic mismatch; and using a short-term buffering of graphemes (Buchwald & Rapp, 2004; Rapp & Kong, 2002) to contrast the initial word with the constituents of the word evoked by the appearance of the drawing. The effectiveness of this online comparison could be directly linked to the semantic and morphological coincidence between the mental image of the word evoked by the drawing and the word that followed.

4.1 Behavioral Results

In the experimental task, initial images were restricted to those designated with the same common verbal label by all 10 individuals who participated in the earlier pilot study, but as this restriction was semantically based, it could favor behavioral decisions in both semantically congruent and semantically incongruent conditions. Our results seem to support this notion, as the AN children obtained a similar amount of correct responses and reaction times while performing the 2 conditions, while showing longer reaction times and a lower number of correct responses when asked to detect orthographic incongruence. Moreover, the best behavioral performances occurred in the semantic incongruence condition; a result that could be due to the fact that the stimuli (words) that acted as semantically incongruent were visually different from those that children could mentally depict on the basis of the subsequent drawing. However, for *semantic congruence,* words should be further analyzed, given the possibility that substitution and adding or omitting letters might have occurred.

The detection of an orthographic error should involve some level of automation in both perceptual and phonological verbal processing, which is only possible to achieve through repeated exposure to printed words and greater reading experience (Echols, West, Stanovich, & Zehr, 1996). The results of this study show that detecting orthographic errors was the most difficult experimental condition to achieve for both groups; probably due to immaturity in such operations as visual word recognition and short-term buffering of graphemes in second grade 8-year-old children.

A simplistic view of naming speed in the current experimental context might suggest that the slow-naming group would have slower responses when identifying orthographic incongruence; however, behavioral results seem to support the hypothesis that naming speed is more closely related to mechanisms that lie behind the temporal-spatial synchronization of specific neural networks involved in accessing the printed patterns of the words in an orthographic lexicon (Coltheart, 2004), than to global processing speed capabilities.

In spite of the significant number of errors that children made while processing orthographic incongruence, the significant differences between the two groups suggest that specific visual-verbal associations could be established at early stages of reading acquisition, relatively independently of the learning of Spanish orthographic rules; as it must be recalled that second-graders have not yet been exposed to those norms.

With respect to reading skills, in the specific case of reading a short narrative text, behavioral results from AN were similar to those described by Roselli, Matute and Ardila (2006) for a sample of 8-to-9-year-old children who attended private schools; a finding that corresponds to the characteristics of AN. In addition, the reading speed achieved in AN was significantly higher than that reached in SN.

Previous studies with native Spanish-speakers have emphasized the relation between naming in a drawing task performance and reading development (Roselli et al., 2006), and that between early letter knowledge and subsequent reading skills (Nicolson & Fawcett, 1995). However, little research on the association between naming and reading speed in Spanish-speakers has been done (González-Garrido et al., 2011).

Regarding the selection criteria, there were significant differences between the groups in letter-naming speed, with non-significant differences for drawing-, number- or color-naming speed. Taken together, the lack of naming differences in the 3 stimuli modalities, and the similar response times shown by the 2 groups while performing the 3 experimental conditions (CO, SI, and OI) would seem not to offer support for the hypothesis that postulates an overall processing speed deficit in slow-naming children (Bravo, Villalón, & Orellana, 2006). Instead, a more likely explanation might be a specific deficit, perhaps linked to acquisition of the reading-writing process and, subsequently, to the automizing of the grapheme-phoneme associations. In fact, the high correlation found between letter-naming and the number of words read per minute seems to emphasize the sensitivity of letter-naming as a predictor of subsequent success on reading, especially reading fluency, as has been reported by our group (Gómez-Velázquez et al., 2010).

Briefly, the data presented here show that letter-naming performance correlates with reading fluency, efficiency and reading comprehension in second grade children. However, the relation between naming speed and reading fluency is not yet fully clear. Bowers, Golden, Kennedy & Young (1994) hypothesized that slow-naming speed could be due to slowness in letter recognition interfering with a faster assembly of orthographic patterns. Reading may then be slow due to a lag in grapheme-phoneme conversion and the unavailability of orthographic representations that would allow direct word recognition. The significant correlation among letter-naming speed, reading fluency and correct responses in OI observed in this study seems to support this notion.

As both the characteristics of the stimuli and the type of pseudohomophone were controlled, results suggest that detection of orthographic violations does not depend on these variables. Therefore, these behavioral results could be interpreted as an index of weaker representations in the orthographic lexicon, or of difficulty in automatically accessing such representations, that lead slow-naming children to depend on a phonologically-based word decoding strategy for a longer time, thus delaying/disturbing reading fluency and competence in recognizing orthographic violations, with the result that they took a pseudohomophone as a real word more frequently than did the subjects in AN.

While in terms of reading, Spanish is a highly regular language, some specific phonemes can be represented by different graphemes when written. As reported by Landerl (2001) for German, orthographical knowledge in SN seems to be very limited and a deficit in writing is a typical feature of dyslexia in German. Something similar is found in Spanish, at least for slow-naming children, who showed significantly greater difficulty in recognizing orthographic violations, as well as more marked reading-writing acquisition problems compared to AN children.

Slow-naming has been related to reading difficulties, and it is well known that children with reading problems tend to avoid reading and thus decrease their orthographic exposure. It has also been reported that orthographical errors might be more closely related to difficulties in storing orthographic representations than to the ability to automate rules (Cervera-Mérida & Ygual-Fernández, 2006); thus, it is possible that exposure to printed material may have influenced the differences found between these 2 groups. However, this is very difficult to quantify, and further research is needed to clarify this point.

4.2 Electrophysiological Results

The ERP from both groups generally concord with the typical morphology usually obtained through so-called "visual matching", or semantic–non semantic visual comparison, tasks (Berti, Geissler, Lachmann, & Mecklinger, 2000; Huang, Itoh, Suwazono, & Nakada, 2004; Klaver, Smid, & Heinze, 1999; Szucs, Soltesz, Czigler, & Csepe, 2007), and that observed when processing visual words in Spanish (Vergara, 2006).

In the present experiment, ERP showed higher voltages for SN children in all study conditions. Voltage increases are usually interpreted as signs of greater neural recruitment, which is commonly seen in more novel tasks or ones that are more difficult (Ciesielski, Harris, & Cofer, 2004). An alternative explanation could be an oversized neural resource allocation (due to an inadequate estimation of task-difficulty), either as part of a Supervisor Attentional System failure, probably due to immaturity of the frontal-parietal cortico-cortical network (Ciesielski, Harris, & Cofer, 2004; Jonkman, Lansbergen, & Stauder, 2003; Smith, Johnstone, & Barry, 2004), or the use of a different cognitive strategy.

A component called N2b, that exhibits peaks around 280 ms in adults, has been reported during performance of category comparison tasks (Szucs et al., 2007; Zhang, Wang, Li, & Wang, 2003). Experimental evidence suggests that while the N400 component is a specific marker of semantic incongruity, N2b represents a general correlate of inconsistencies in the detection process, or "conflicts" (Zhang et al., 2003) between representations of task-relevant stimuli features (Szucs et al., 2007).

As the experimental task used in this work did not compare two visual patterns from an equivalent order (i.e. word-word, or image-image), two hypothetical ERP components were primarily expected: 1) an N2-like waveform for orthographic incongruence, as an electrophysiological marker of a generic conflict between stimuli, given that despite morphological incongruence, semantic content and word phonological representation match expectations; and, 2) an N400 waveform reflecting semantic incongruence for condition SI. However, both conditions showed early negativity in AN as likely analogous to N2b, where differences between conditions did not correspond to the latency and distribution of the component but, rather, with its amplitude. These results suggest that the most efficient strategy for solving the task would probably consist in generating a mental orthographic pattern of the most expected written word to compare "online" with the one that actually appears, rather than making comparisons of meaning. The slight rightward lateralization of the P450 component seems to support this hypothesis, given the right cerebral hemisphere's visuospatial processing skills.

In general, late positivities are usually interpreted as indexes of task-difficulty or, alternatively, as reflecting the response preparation period. Given the latency and distribution of P480, it can be interpreted as an analogue of the P300 component, which appears when a stimulus is perceived and attentional resource allocation and memory operations are involved (see Polich et al., 1997 for a review), which seems to be the present case, with greater emphasis on the orthographic incongruent condition.

Briefly, the SN and AN groups showed significant differences in the number of correct responses while detecting orthographic violations, but not in reaction times, thus weakening the hypothesis that a general processing speed deficit could underlie performance. A specific visual word processing deficit seems more likely to explain the marked reading slowness in SN, as it also limits the use of more appropriate global reading strategies.

It has been stated that underlying naming-speed deficit is the difficulty in building up adequate associations between visual and phonological representations of words. This limits the development of a visual repertoire of common words, thus leading to both lower reading fluency and difficulties when writing (Wolf & Bowers, 1999). Our results seem to corroborate this perspective. Despite the early age of the children studied and their limited reading experience, it seems that AN had already stored more orthographic information that allowed them to successfully recognize significantly more orthographic violations than SN. However, further studies must be carried out to generalize these results.

References

Abrams, D. A., Nicol, T., Zecker, S., & Kraus, N. (2009). Abnormal cortical processing of the syllable rate of speech in poor readers. *The Journal of Neuroscience, 29,* 7686-7693. http://dx.doi.org/10.1523/JNEUROSCI.5242-08.2009

Annett, M. (1970). A classification of hand preference by association analysis. *British Journal of Psychology, 61*, 303-321. http://dx.doi.org/10.1111/j.2044-8295.1970.tb01248.x

Berti, S., Geissler, H., Lachmann, T., & Mecklinger, A. (2000). Event-related brain potentials dissociate visual working memory processes under categorial and identical comparison conditions. *Brain Research Cognitive Brain Research, 9,* 147-155. http://dx.doi.org/10.1016/S0926-6410(99)00051-8

Bowers, P. G., Golden, J., Kennedy, A., & Young, A. (1994). Limits upon orthographic knowledge due to processes indexed by naming speed. In V. W. Berninger (Ed.), *The varieties of orthographic knowledge: Theoretical and developmental issues* (pp. 173-218). Dordrecht, The Netherlands: Kluwer.

Bowers, P. G., Sunseth, K., & Golden, J. (1999). The route between rapid naming and reading progress. *Scientific Studies of Reading, 3,* 31-53. http://dx.doi.org/10.1207/s1532799xssr0301_2

Bowers, P. G., & Wolf, M. (1993). Theoretical links among naming speed, precise timing mechanisms and orthographic skill in dyslexia. *Reading and Writing: An interdisciplinary Journal, 5,* 69-85. http://dx.doi.org/10.1007/BF01026919

Bradley, L., & Bryant, P. E. (1978). Difficulties in auditory organization as a possible cause of reading backwardness. *Nature, 271*, 746–747. http://dx.doi.org/10.1038/271746a0

Braun, M., Hutzler, F., Ziegler, J. C., Dambacher. M., & Jacobs, A. M. (2009). Pseudohomophone effects provide evidence of early lexico-phonological processing in visual word recognition. *Human Brain Mapping, 30,* 1977-1989. http://dx.doi.org/10.1002/hbm.20643

Bravo, V. L., Villalón, M., & Orellana, E. (2006). Diferencias en la predictividad de la lectura entre primer año y cuarto año básicos. *Psykhe, 15,* 3-11. http://dx.doi.org/10.4067/S0718-22282006000100001

Brem, S., Bach, S., Kucian, K., Guttorm, T. K., Martin, E., Lyytinen, H., Brandeis, D., & Richardson, U. (2010). Brain sensitivity to print emerges when children learn letter-speech sound correspondences. *Proceedings of the National Academy of Sciences of the United States of America, 107*, 7939-7944. http://dx.doi.org/10.1073/pnas.0904402107

Briesemeister, B. B., Hofmann, M. J., Tamm, S., Kuchinke, L., Braun, M. M., & Jacobs A. M. (2009). The pseudohomophone effect: Evidence for an orthography-phonology-conflict. *Neuroscience Letters, 455,* 124-128. http://dx.doi.org/10.1016/j.neulet.2009.03.010

Buchwald, A., & Rapp, B. (2004). Rethinking the graphemic buffer? *Brain and Language, 91,* 100-101. http://dx.doi.org/10.1016/j.bandl.2004.06.052

Cao, X. H., & Zhang, H. T. (2011). Change in subtle N170 specialization in response to Chinese characters and pseudocharacters. *Perceptual and motor skills, 113,* 365-376. http://dx.doi.org/10.2466/04.22.24.28.PMS.113.5.365-376

Carreiras, M., Perea, M., Vergara, M., & Pollatsek, A. (2009). The time course of orthography and phonology: ERP correlates of masked priming effects in Spanish. *Psychophysiology, 46,* 1113-1122. http://dx.doi.org/10.1111/j.1469-8986.2009.00844.x

Cervera-Mérida, J. F., & Ygual-Fernández, A. (2006). Una propuesta de intervención en trastornos disortográficos atendiendo a la semiología de los errores. *Revista de Neurología 42,* 117-126.

Ciesielski, K. T., Harris, R. J., & Cofer, L. F. (2004). Posterior brain ERP patterns related to the go/no-go task in children. *Psychophysiology, 41,* 882-892. http://dx.doi.org/10.1111/j.1469-8986.2004.00250.x

Coltheart, M. (2004). Are there lexicons? *The Quarterly Journal of Experimental Psychology, 57,* 1153-1171. http://dx.doi.org/10.1080/02724980443000007

Denckla, M. B., & Rudel, R. D. (1976). Naming of objects by dyslexics and other learning- disabled children. *Brain and Language, 3,* 1-15. http://dx.doi.org/10.1016/0093-934X(76)90001-8

Echols, L. D., West, R. F., Stanovich, K. E., & Zehr, K. S. (1996). Using children's literacy activities to predict growth in verbal cognitive skills: A longitudinal investigation. *Journal of Educational Psychology, 88,* 296-304.

Escribano, C. L. (2007). Evaluation of the double-deficit hypothesis subtype classification of readers in Spanish. *Journal of Learning Disabilities, 40,* 319-330. http://dx.doi.org/10.1177/00222194070400040301

Friedmann, N., & Lukov, L. (2008). Developmental surface dyslexias. *Cortex, 44,* 1146-1160. http://dx.doi.org/10.1016/j.cortex.2007.09.005

Gómez-Velázquez, F. R., González-Garrido, A. A., Zarabozo, D., & Amano, F. (2010). La velocidad de denominación de letras es el mejor predictor temprano del desarrollo lector en español. *Revista Mexicana de Investigación Educativa, 15,* 823-847.

González-Garrido A. A., Gómez-Velázquez F. R., Zarabozo D., Ruiz-Villeda B. A., & de la Serna Tuya, J. M. (2011). Rapid automatized naming and lexical decision in children from an electrophysiological perspective. *Clinical EEG & Neuroscience, 42,* 14-23. http://dx.doi.org/10.1177/155005941104200106

Goswami, U. (2002). Phonology, reading development, and dyslexia: A cross-linguistic perspective. *Annals of Dyslexia, 52,* 139-163. http://dx.doi.org/10.1007/s11881-002-0010-0

Goswami, U., Gombert, J. E., & Fraca de Barrera, L. (1998). Children's orthographic representations and linguistic transparency: Nonsense word reading in English, French and Spanish. *Applied Psycholinguistics 19,* 19-52. http://dx.doi.org/10.1017/S0142716400010560

Hauk, O., Davis, M. H., Ford, M., Pulvermüller, F., & Marslen-Wilson, W. D. (2005). The time course of visual word recognition as revealed by linear regression analysis of ERP data. *Neuroimage, 30,* 1383-1400. http://dx.doi.org/10.1016/j.neuroimage.2005.11.048

Hauk, O., Pulvermüller, F., Ford, M., Marslen-Wilson, W. D., & Davis, M. H. (2009). Can I have a quick word? Early electrophysiological manifestations of psycholinguistic processes revealed by event-related regression analysis of the EEG. *Biological Psychology, 80*, 64-74. http://dx.doi.org/10.1016/j.biopsycho.2008.04.015

Holyk, G. G., & Pexman, P. M. (2004). The elusive nature of early phonological priming effects: are there individual differences*? Brain and Language, 90,* 353-367. http://dx.doi.org/10.1016/S0093-934X(03)00447-4

Huang, K., Itoh, K., Suwazono, S., & Nakada, T. (2004). Electrophysiological correlates of grapheme-phoneme conversion. *Neuroscience Letters, 366,* 254-258. http://dx.doi.org/10.1016/j.neulet.2004.05.099

Jonkman, L. M., Lansbergen, M., & Stauder, J. E. (2003). Developmental differences in behavioral and event-related brain responses associated with response preparation and inhibition in a go/no go task. *Psychophysiology, 40,* 752-761. http://dx.doi.org/10.1111/1469-8986.00075

King, W. M., Lombardino, L. L., & Ahmed, S. (2005). Accuracy and speed of orthographic processing in persons with developmental dyslexia. *Perceptual and motor skills, 101,* 95-107. http://dx.doi.org/10.2466/pms.101.1.95-107

Klaver, P., Smid, H. G., & Heinze, H. J. (1999). Representations in human visual short-term memory: an event-related brain potential study. *Neuroscience Letters, 268,* 65-68. http://dx.doi.org/10.1016/S0304-3940(99)00380-8

Landerl, K. (2001). Word Recognition deficits in German: More evidence from a representative sample. *Dyslexia 7,* 183-196. http://dx.doi.org/10.1016/S0304-3940(99)00380-8

Landerl, K., & Wimmer, H. (2008). Development of word reading fluency and orthographic spelling in a consistent orthography: An 8-year follow-up. *Journal of Educational Psychology, 100,* 150-161. http://dx.doi.org/10.1037/0022-0663.100.1.150

Leal, C. F., & Suro, S. J. (2006). Análisis fonológico de la ejecución de niños con trastornos de lectura. In B. Gallardo, C. Hernández y V. Moreno (eds.). *Lingüística clínica y neuropsicología cognitiva* (pp. 153-172). Actas del Primer Congreso Nacional de Lingüística Clínica. V 2: Lingüística y evaluación del lenguaje.

Lovett, M. W., Ransby, M. J., & Barron, R. W. (1998). Treatment, subtype, and word type effects in dyslexic children's response to remediation. *Brain and Language, 34,* 328-349. http://dx.doi.org/10.1016/0093-934X(88)90143-5

Meyler, A., & Breznitz, Z. (2005). Visual, auditory and cross-modal processing of linguistic and nonlinguistic temporal patterns among adult dyslexic readers. *Dyslexia, 11,* 93-115. http://dx.doi.org/10.1002/dys.294

MindTracer. (2003). *Manual del usuario.* Versión 2.0. Havana, Cuba: Neuronic, S.A.

Münte, T. F., Heinze, H., Matzke, M., Wieringa, B. M., & Johannes, S. (1997). Brain potentials and syntactic violations revisited: no evidence for specificity of the syntactic positive shift. *Neuropsychologia, 36,* 217-226. http://dx.doi.org/10.1016/S0028-3932(97)00119-X

Newman, S. D. (2011). The homophone effect during visual word recognition in children: an fMRI study. *Psychological Research, 76,* 280-291. http://dx.doi.org/10.1007/s00426-011-0347-2.

Newman, R. L., & Connolly, J. F. (2004). Determining the role of phonology in silent reading using event-related brain potentials. *Cognitive Brain Research, 21,* 94-105. http://dx.doi.org/10.1016/j.cogbrainres.2004.05.006

Nicolson, R. I., & Fawcett, A. J. (1995). Dyslexia is more than a phonological disability. *Dyslexia, 1,* 19-36.

Pexman, P. M., Lupker, S. J., & Jared, D. (2001). Homophone effects in lexical decision. *Journal of Experimental Psychology: Learning Memory and Cognition, 27,* 139-156. http://dx.doi.org/10.1037/0278-7393.27.1.139

Polich, J., Alexander, J. E., Bauer, L. O., Kuperman, S., Morzorati, S., O'Connor, S. J., Porjesz, B., Rohrbaugh, J., & Begleiter, H. (1997). P300 topography of amplitude/latency correlations. *Brain Topography, 9,* 275-282. http://dx.doi.org/10.1007/BF01464482

Rapp, B., & Kong, D. (2002). Revealing the component functions of the graphemic buffer. *Brain and Language, 83,* 112-114.

Roselli, M., Matute, E., & Ardila, A. (2006). Predictores neuropsicológicos de la lectura en Español. *Revista de Neurología, 42,* 202-210.

Sauseng, P., Bergmann, J., & Wimmer, H. (2004). When does the brain register deviances from standard word spellings? – An ERP study. *Cognitive Brain Research, 20,* 529-532. http://dx.doi.org/10.1016/j.cogbrainres.2004.04.008

Seki, A., Okada, T., Koeda, T., & Sadato, N. (2004). Phonemic manipulation in Japanese: an fMRI study. *Brain Research Cognitive Brain Research, 20,* 261-272. http://dx.doi.org/10.1016/j.cogbrainres.2004.03.012

Serrano, F., & Defior, S. (2008). Dyslexia speed problems in a transparent orthography. *Annals of Dyslexia, 58*, 81-95. http://dx.doi.org/10.1007/s11881-008-0013-6

Seymour, P. H. K., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of Psychology, 94,* 143-174. http://dx.doi.org/10.1348%2f000712603321661859

Smith, J. L., Johnstone, S. J., & Barry, R. J. (2004). Inhibitory processing during the Go/No Go task: an ERP analysis of children with attention deficit/hyperactivity disorder. *Clinical Neurophysiology, 115,* 1320-1331. http://dx.doi.org/10.1016/j.clinph.2003.12.027

Stanovich, K. E., & West, R. F. (1979). The effect of orthographic structure on the word search performance of good and poor readers. *Journal of Experimental Child Psychology, 28,* 258-267. http://dx.doi.org/10.1016/0022-0965(79)90088-2

Szucs, D., Soltesz, F., Czigler, I., & Csepe, V. (2007). Electroencephalography effects to semantic and non-semantic mismatch in properties of visually presented single-characters: the N2b and the N400. *Neuroscience Letters, 412,* 18-23. http://dx.doi.org/10.1016/j.neulet.2006.08.090

Unsworth, S. J., & Pexman, P. M. (2003). The impact of reader skill on phonological processing in visual word recognition. *The Quaterly Journal of Experimental Psychology, 56,* 63-81. http://dx.doi.org/10.1080/02724980244000206

Vergara, M. (2006). Efectos silábicos en el componente P200 durante el procesamiento visual de palabras: un estudio de potenciales relacionados con eventos. *Cognitiva, 18,* 25-41. http://dx.doi.org/10.1174/021435506775462427

Vissers, C. Th. W. M., Chwilla, D. J., & Kolk, H. H. J. (2006). Monitoring in language perception: the effect of misspellings of words in highly constrained sentences. *Brain Research, 1106,* 150-163. http://dx.doi.org/10.1016/j.brainres.2006.05.012

Wechsler D. (1984). *WISC-RM. Escala de Inteligencia revisada para el nivel escolar.* México: Manual Moderno.

Wimmer, H. (1993). Characteristics of developmental dyslexia in a regular writing system. *Applied Psycholinguistics, 14,* 1-33. http://dx.doi.org/10.1017/S0142716400010122

Wolf, M., & Bowers, P. G. (1999). The double deficit for the developmental dyslexia. *Journal of Education Psychology, 91,* 415-438. http://dx.doi.org/10.1037/0022-0663.91.3.415

Zhang, X., Wang, Y., Li, S., & Wang, L. (2003). Event-related potential N270, a negative component to identification of conflicting information following memory retrieval. *Clinical Neurophysiology, 114,* 2461-2468. http://dx.doi.org/10.1016/S1388-2457(03)00251-7