anuario de

# psicología

The UB Journal of Psychology

Volumen 44
Número 3
Diciembre 2014

facultad de psicología
universidad de barcelona

HORSORI
EDITORIAL

ISSN: 0066-5126
ISSN: 1988-5253

*Anuario de Psicología/The UB Journal of Psychology*
2014, vol. 44, nº 3, 267-282
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Universitat de Barcelona

# Neuroimage study on low orthographic competence group*

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Background: *In this paper we studied the functional neural substrates underlying the performance of homophonic spelling error detecting tasks- including frequent and infrequent Spanish words- through functional Magnetic Resonance Imaging (*fMRI*) procedure in subjects with low orthographic performance.* Method: *A block design was used to administer 2 visual tasks, with 2 experimental conditions each, to 8 healthy participants with low orthographic performance. In both tasks correct and misspelled Spanish words sequentially appeared. Participants were instructed to detect orthographic errors in one task, as well as the presence of 1 specific vowel in the other. Image data were obtained from 32 axial contiguous slices and repetition time of 3 seconds.* Results: *Significant bilateral activations were found, especially in medial temporal areas during the orthographic error recognition task performance, whereas upper right and left frontal regions were significantly activated while detecting a specific vowel.* Conclusions: *These data are consistent with the literature and suggest an association between orthographic processing and hyperactivation of bilateral cerebral areas in subjects with low orthographic skills, probably due to compensatory mechanisms.*
Keywords: *Spelling, reading, visual word recognition, functional Magnetic Resonance Imaging, BOLD signal.*

* *Ackowledgements*: The study was funded by the National Science and Technology Council (CONACyT) of Mexico, SEP-CONACYT project number CB-2012-183561. Special thanks to Bañuelos Radiologists group Guadalajara (Mexico) for their help to perform the *f*MRI studies in their facilities, as well as to Ms. Alicia Martínez Ramos, Ms. Geisa Bearitz Gallardo & Ms. Miriam Jiménez for their essential help during the experimental sessions.
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# Estudio de neuroimagen en sujetos con baja competencia ortográfica ante tareas ortográficas con errores homófonos

Antecedentes: *En este trabajo se estudia la implicación de regiones cerebrales en la detección de errores ortográficos de tipo homófono en palabras frecuentes e infrecuentes del español mediante Imagen por Resonancia Magnética funcional (IRMf) en sujetos de bajo desempeño ortográfico.* Método: *Se empleó un Diseño de Bloques para presentar visualmente 2 tareas y 2 condiciones experimentales a ocho sujetos sanos con bajo desempeño ortográfico. Se presentaron palabras correcta e incorrectamente escritas solicitándoles a los participantes, en la primera tarea, que detectaran la presencia de errores ortográficos, mientras que en la segunda se solicitaba que detectaran la presencia de una vocal específica en la palabra presentada. Las imágenes se registraron a partir de 32 cortes axiales contiguos con un tiempo de repetición de 3 segundos.* Resultados: *Se encontraron activaciones significativas en áreas temporales y mediales, de forma bilateral, en la tarea de reconocimiento de patrón ortográfico mientras que en la tarea de detección de vocales las activaciones significativas se observaron en la región frontal superior derecha y frontal izquierda.* Conclusiones: *Los resultados son congruentes con lo reportado en la bibliografía y sugieren que el pobre reconocimiento ortográfico se asocia con hiperactivación neural bilateral cuando se ejecutan tareas de este orden, a modo de un posible reclutamiento compensatorio.*

Palabras clave: *ortografía, lectura, reconocimiento visual de palabras, Resonancia Magnética funcional, señal BOLD.*

## Introduction

Reading is a complex cognitive process that requires the development and appropriate use of different morphological, orthographic, phonological and semantic processing skills. Visual word recognition is a crucial component of the reading process. From a functional-anatomical perspective, this process involves different neural networks whose expertise and progressive integration into a new neural network is a direct consequence of literacy and exposure to texts. Several functional imaging studies have identified specific word-processing areas in the occipito-temporal region (Kanwisher, Downing, Epstein, & Kourtzi, 2006). It is common knowledge that the greatest advantage of the functional magnetic resonance imaging (*f*MRI) technique is the accurate spatial localization of a cognitive processes, assuming that an active process is reflected by a regional increase of neuronal activity and blood flow (Bandettini et al., 1997; Buxton, 2002; Haacke, Brown, Thompson, & Venkatesan, 1999; Vendrell, Junque, & Pujol, 1995).

The blood-oxygen-level dependent (BOLD) technique is the most commonly used *f*MRI imaging technique because of its noninvasive nature (Logothetis,


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2002; Logothetis, Pauls, Augath, Trinath, & Oeltermann, 2001; Ogawa, Lee, Kay, & Tank, 1990). Hence, even though the *f*MRI (based on the BOLD signal) is not a direct measure of neuronal activity or metabolic activity, it certainly measures the magnetic changes due to neural metabolic demand, which are related to the increase of local blood flow as a result of a more specific involvement of certain brain regions during a cognitive function (Binder & Price, 2006; Huettel, Song, & McCarthy, 2009).

## *Visual word recognition and f*MRI

Imaging methods have impetuously advanced in recent years and in the case of *f*MRI, it has repeatedly proven useful for the assessment of different cognitive processes (Binder & Price, 2006; Vendrell et al., 1995), particularly in literacy (Nakamura et al., 2012; Schlaggar & McCandliss, 2007). Numerous studies suggest the existence of two major neural circuits involved in literacy, one posterior and one anterior. The former is divided into two branches, a ventral pathway mainly formed by the occipital-temporal region or the left fusiform circumvolution and lingual areas, commonly termed as *Visual Word Form Area* (VWFA; Cohen et al., 2000); and a dorsal pathway, mainly formed by the angular, supramarginal and superior temporal circumvolutions. It has been proposed that the ventral branch underlies the coarse morphological analysis of words and linguistic stimuli (Cohen et al, 2000; Woodhead, Brownsett, Dhanjal, Beckmann, & Wise, 2011; Xue & Poldrack, 2007), while its dorsal branch participates in the phonological analysis of visual information (Binder et al., 1997). Cerebral specialization for reading words in the posterior ventral circuit (medial area of the left fusiform circumvolution) is strongly lateralized to the left (Cohen et al., 2000; Dehaene & Cohen, 2011) and it has been compared with the specialization achieved by the brain areas involved in face detection (FFA-*Fusiform Face Area*-), located over the right occipito-temporal region, which is mainly formed by the fusiform circumvolution (Gauthier et al., 2000; Kanwisher et al., 2006). On the other hand, the anterior circuit is mainly formed by the frontal inferior circumvolution, which has been proposed as a participant in a finer quality analysis of written language and phonological recoding (Fiez, 1997; Gabrieli, Poldrack, & Desmond, 1998; Marslen-Wilson & Tyler, 2007).

In *f*MRI studies the quantification of the participation level or activation of the mentioned circuits has been done in tasks that assess any of the mentioned processes. Those studies have allowed the identification of functional differences between normal readers and those with deficiencies in reading accuracy, reading speed, or both. Some authors have postulated that the activations in BOLD signal generally increases as the reader acquires expertise (Shaywitz & Shaywitz, 2005), while others have found hyperactivation of the anterior circuit


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in poor readers (Pugh et al., 2000) arguing compensatory mechanisms during cognitive performance. In this sense, functional bilateral activation as an alternative compensatory mechanism in poor readers has also been proposed (Gebauer et al., 2012).

### *Visual word recognition and orthographic transparency*

The vast majority of studies related to visual perception and word processing have been performed in languages with opaque orthographies, in which there is low correspondence between letters and sounds, i.e. letters have different sounds depending on the word (English, e.g.: *man*, *make*, *walk*, in which the grapheme "a" represents three distinct phonemes /æ/, /i/ and /ɔI/). In contrast, spelling in Spanish is considered "transparent", due to the high letter-sound correspondence (e.g. *casa -house-*, *paraguas -umbrella-*, *planta -plant-*, where the grapheme "a", regardless its position or the word in which it appears, it always represents the phoneme /a/). Considering that learning to read is influenced by the characteristics of the orthography of the language and the grapheme-phoneme relationship, one could expect differences in underlying brain mechanisms in English and Spanish. The difficulties in the acquisition of the alphabetic principle involving grapheme-phoneme conversion have been associated with slow naming speed (Bowers & Wolf, 1993) and a low reading fluency (Landerl & Wimmer, 2008). A low reading speed has also been considered as the fundamental feature of dyslexia in Spanish (Gómez-Velázquez, González-Garrido, Zarabozo, & Amano, 2010, López-Escribano, 2007; Serrano & Defior, 2008).

In transparent orthographies for reading, such as Spanish or German, there are more difficulties in writing, because a phoneme could be represented by more than one grapheme (as in the case of /s/ represented by c-s-z in Latin American Spanish), leading to homophone errors. However, this topic has not been given sufficient attention (Gebauer et al., 2012; Kronbichler et al., 2007). This notion coincides with evidence obtained from studies on the brain areas involved in reading and their complex relationships with different orthographic systems, including several perspectives as those proposed by Frost (1994), Paulesu et al. (2000), or by Ziegler, Perry, Jacobs, & Braun (2001). These studies have underlined the Orthographic Depth Hypothesis (ODH), which constitutes the theoretical foundation of the present work.

It seems reasonable to expect that differences in the transparency of languages like those occurring in English and Spanish could determine changes in functional neural substrates involved in each language spelling. Furthermore, less transparency for writing in Spanish causes more difficulties in the orthographic recognition, especially in those individuals with lower writing skills, in whom the presence of reading difficulties has also been reported (González-Garrido, Gómez-Velázquez, & Rodríguez-Santillán, 2014). Following this line of


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research, the present study aims to evaluate, through *f*MRI and BOLD signal processing methods, the brain functional activation patterns in a group of young adults with low spelling performance during the execution of two lexical tasks relying on the orthographic analysis. One could expect that subjects with low orthographic skills might need a compensatory hyperactivation in orthographic processing neural structures, particularly on ventral-posterior circuits. It is not a comparison with high orthographic performance subjects since orthographic tasks in this work don't require special resources in highly qualified persons in spelling tasks. Contrary to subjects with low competition, the homophone errors acquire an interference role that is absent in other populations. In brief, the present work must be regarded as strictly descriptive for the estimation of brain areas activated in tasks including homophone spelling errors in subjects with low spelling abilities, who are native speakers in a transparent language like Spanish used in Latin America.

## Methods

### *Participants*

Eight young adults ($M$ = 20.13 years, $SD$ = 1.11, 3 female) participated voluntarily. At the time of the records, they were seniors in high school or attending the first year of college education ($M$ = 12 years, $SD$ = 0.39) of various schools in the city of Guadalajara (Mexico). All were right-handed according to the Handedness Inventory (Oldfield, 1971), none had a history of neurological disorder or learning disorder and had normal or corrected vision. All signed an informed consent and were financially compensated for their participation (25 €). Participants were intentionally selected to have low scores in five tasks that assessed the detection of misspellings of homophone type into four groups of graphemes (b-v, c-s-z, ll-y h-without h): word completing, letter dictation, word dictation, error detection task in a text, and free writing. The 8 participants had a performance below the first quartile for the total correct responses in the five tasks described in relation to the distribution observed for a larger sample of the same socio-demographic data characteristics (Gómez-Velázquez, González-Garrido, Guàrdia-Olmos, Peró-Cebollero, Zarabozo-Hurtado, & Zarabozo, 2014).

### *Stimuli and procedure*

Sixty correctly spelled and 20 including 1-homophone error (e.g. "*sapato*" instead of the correctly spelled "*zapato*") words in Spanish were presented in


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white characters on a black background using a font arial 60 and 300 pixels per inch. The words were common and uncommon according to a frequency dictionary designed in our laboratory, and compared with those of computerized Lexicon -LEXESP- Spanish (Sebastián, Martí, Carreiras, & Cuetos, 2000), controlling the frequency range to prevent biased results, due to very high or low frequencies are associated with different activations (Cuetos, Gonzalez-Nosti, Barbón, & Brysbaert, 2011).

Stimuli were sequentially presented for 1 second, with an ISI of one second. They were pseudo-randomly divided into 8 blocks of 10 stimuli each. Four blocks included misspelling words (A1, A2, C1 and C2) and the remaining 4 only the correct ones (B1, B2, D1, D2). Table 1 (see next page) summarizes the experimental conditions. The blocks in each of the experimental tasks were counterbalanced to avoid bias effects subsequent to their presentation order. Prior to each stimuli block, a resting activation block (R) with black screen and a fixation point was presented; in which the subject had none specific action to make. The fixation point changed its color indicating the beginning of each trial. Both tasks were administered randomly among the subjects. In the first task (conscious detection) participants had to decide whether the presented word was correctly spelled or not, taking the decision by pressing one of two buttons on a keyboard. The keyboard consists of a rectangular box with two buttons on top; easy to press and directly connected to the central computer that recorded the responses. In the second task (unconscious detection) participants had to decide whether the presented word contained the letter *"i"* taking their decision through the same device buttons. Figure 1 (see page 274) schematically shows the Block Design used. The tasks were explained to all the participants before they were recorded in the resonance device. The contrasts were performed within -and between-tasks in relation to baseline, according to the assumptions of mass linear models that are typically used in this type of analysis.

## *f*MRI *Image acquisition*

*f*MRI data were acquired on a GE Sigma Excite HDxT 1.5 T scanner (GE Medical Systems, Milwaukee, WI). High-resolution 8 channels quadrature antenna was used. T1-weighted anatomical reference images were acquired using a spoiled-gradient-echo sequence (SPGR, GE Medical Systems, Milwaukee, WI). Functional images used a BOLD EPI-GRE (blood-oxygen level dependent echo planar imaging gradient-echo) sequence with 32 contiguous slices, 4 mm thickness with no gap and 4.06 x 4.06 mm in plane resolution; TR = 2000 ms, TE = 40 ms, flip angle = 90, echo time = 60 ms, and FOV = 26 cm. A total of 62 whole-brain volumes were obtained for each experimental task.


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*TABLE 1. STIMULI FREQUENCY – ABSOLUTE FREQUENCY, NUMBER OF ELEMENTS PER MILLION IN THE CORPUS.*

| **Block** | **Word** | **Frequency** | | **Block** | **Word** | **Frequency** | |
|---|---|---|---|---|---|---|---|
| | | **Lab** | **LEXESP** | | | **Lab** | **LEXESP** |
| **A1** | hielo | 44 | 31 | **C1** | gente | 171 | 277 |
| | región | 197 | 44 | | evento | 3 | 10 |
| | harina | 16 | 7 | | labor | 100 | 40 |
| | osono | 2 | 9 | | acha | 4 | 6 |
| | abilidad | 16 | 27 | | cueba | 12 | 10 |
| | anzuelo | 1 | 3 | | gabilán | 2 | 1 |
| | orno | 6 | 7 | | ampoya | 1 | 1 |
| | aliansa | 57 | 15 | | collar | 4 | 6 |
| | olvido | 11 | 31 | | joya | 3 | 5 |
| | larba | 1 | 2 | | corvata | 2 | 17 |
| **B1** | resorte | 1 | 4 | **D1** | tarjeta | 4 | 14 |
| | huacal | 1 | --- | | eclipse | 2 | 1 |
| | onza | 2 | 1 | | membrillo | 1 | 1 |
| | jabón | 10 | 9 | | huarache | 1 | --- |
| | proyecto | 2 | 106 | | jarabe | 3 | 1 |
| | grillo | 21 | 1 | | hule | 5 | 2 |
| | abeja | 33 | 4 | | agente | 25 | 27 |
| | hoja | 21 | 26 | | maíz | 64 | 11 |
| | cine | 1 | 123 | | hormiga | 11 | 5 |
| | camisa | 10 | 30 | | resina | 3 | 5 |
| **A2** | noticia | 46 | 71 | **C2** | avión | 16 | 50 |
| | graniso | 1 | 2 | | creación | 151 | 54 |
| | consepto | 79 | 66 | | escuela | 151 | 56 |
| | expansión | 18 | 21 | | abena | 1 | 1 |
| | albergue | 5 | 3 | | gitano | 1 | 9 |
| | uracán | 4 | 4 | | eroción | 1 | 4 |
| | jemido | 4 | 5 | | corasón | 111 | 151 |
| | cinturón | 5 | 15 | | ormona | 20 | 10 |
| | dulse | 35 | 39 | | epopella | 4 | 4 |
| | caudillo | 28 | 6 | | nave | 23 | 28 |
| **B2** | durazno | 3 | 1 | **D2** | códice | 2 | 1 |
| | almacén | 2 | 13 | | estadio | 2 | 25 |
| | príncipe | 26 | 23 | | inventor | 7 | 6 |
| | carbón | 34 | 17 | | ventana | 33 | 93 |
| | glaciar | 4 | 2 | | trenza | 5 | 3 |
| | dígito | 1 | 1 | | capilla | 1 | 18 |
| | tesoro | 13 | 15 | | laringe | 1 | 1 |
| | camello | 3 | 2 | | taquilla | 2 | 3 |
| | insecto | 12 | 6 | | crayola | 1 | --- |
| | empresa | 116 | 115 | | globo | 14 | 10 |

*Note*. Blocks A1, A2, C1 and C2 contain misspelled words, while the remaining blocks only contain correct words. In blocks A1, A2, B1 and B2, participants must indicate if the word is correctly written or not. In C1, C2,


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D1 and D2 blocks, participants were instructed to identify if the word contained a letter "i" or not, regardless of whether it is well written or not. Lab: frequency dictionary made in the laboratory of neurosciences at the University of Guadalajara. LEXESP: Spanish digital lexicon.

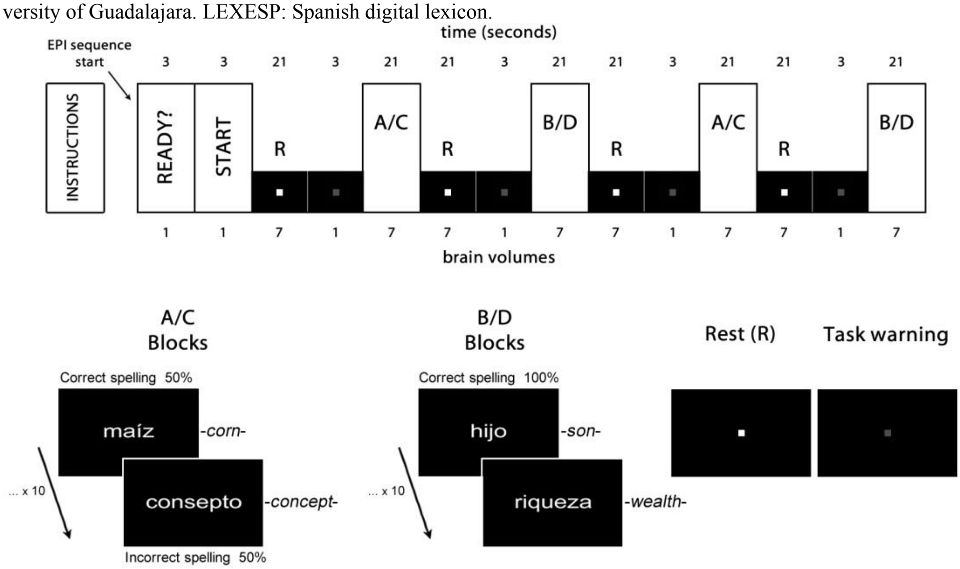


*Figure 1.* Experimental design of both tasks – Rest (R) and activation (A,B,C, and D) blocks. For imaging analyses, brain volumes corresponding to "¿LISTO? -*READY?*-", "COMENZAMOS -*START*-", and task warning (green fixation point) were eliminated.

All functional images were transferred to offline workstations using DICOM format and analyzed using SPM8 (http://www.fil.ion.ucl.ac.uk/spm/software/spm8/) software package in which preprocessing steps and statistical analysis were carried on. The volumes corresponding to start session and start stimulation warnings were both excluded. The final amount of brain volumes per task was 56. The images were spatially realigned, readjusted according to the voxel size, and normalized rendering the MNI reference -Montreal Neurological Institute- and Talairach coordinates. A Kernel Gaussian filter threefold voxel size in the x, y, z axes was used. The images shown in the results section were obtained using the MRIcron software (http://www.mricron.com), starting from the statistical parametric maps created by SPM8; setting a corrected value of $\alpha = .001$.

## Results

The behavioral results suggest that the time spent by the participants to solve the tasks depended upon the task nature. Longer reaction times and higher amount


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of omissions were observed when performing the spelling task (table 2). However, when the participants were asked to detect a single letter in a word, they almost had a perfect performance, with scarce amount of omissions, even though the proportion of correct and misspelled words were the same in both tasks. The results shown in table 2 are very expressive, but given the sample size, nonparametric tests were used to estimate the effects between tasks. All statistics test were significant ($p$ <.001), implying that when participants had to perform the lexical decision, two large clusters of bilateral activations over temporal and parietal regions, as well as a small cluster of higher functional activity on the vermis of the right cerebellar hemisphere and other active areas corresponding to the posterior cingulate and precuneus (table 3 and figure 2) are significant. Thus, these comparisons between activations from tasks A and B showed statistical significance effects [$F$(1,784) = 12.218; $p$ <.001].

*TABLE 2. BEHAVIORAL RESULTS – MEAN (STANDARD DEVIATION) AND MAXIMUM & MINIMUM VALUES IN THE FOUR EXPERIMENTAL BLOCKS.*

| | ***Blocks*** | | | |
|---|---|---|---|---|
| | *A* | *B* | *C* | *D* |
| *Reaction Times ** | 863.86 (29.05) | 809.76 (36.53) | 690.69 (77.42) | 670.28 (61.44) |
| *Correct Responses* | 8.25 (2.12)<br>5 – 12 | 12.50 (1.07)<br>11 – 14 | 17.13 (2.59)<br>13 – 20 | 18.38 (0.74)<br>17 – 19 |
| *Incorrect Responses* | 2.63 (2.07)<br>1 – 7 | 1.63 (1.60)<br>0 – 4 | 0.38 (0.52)<br>0 – 1 | 0.25 (0.46)<br>0 – 1 |
| *Omissions* | 9.12 (3.80)<br>1 – 14 | 5.88 (2.03)<br>2 – 8 | 2.50 (2.56)<br>0 – 7 | 1.38 (0.92)<br>0 – 3 |

*Note.* Blocks A1, A2, C1 and C2 contain misspelled words, while the remaining blocks only contain correct words. In blocks A1, A2, B1 and B2, participants must indicate if the word is correctly written or not. In C1, C2, D1 and D2 blocks, participants were instructed to identify if the word contained a letter "i" or not, regardless of whether it is well written or not.
* Measured in miliseconds


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Moreover, when participants had to visually recognize words and decide if they contained the letter "i" or not, there were only found 2 small significantly activated clusters, one at the right superior frontal hemisphere and the other at the precentral frontal lobe region (table 3 and figure 3). As it happened before, there were statistical significant effects when comparing the activations between tasks C and D [$F(1,784) = 9.198$; $p < .001$].

*TABLE 3. ACTIVATION PEAKS WHERE BOLD SIGNAL INCREASED – ACCORDING TO THE EXPERIMENTAL CONDITION, HEMISPHERE (L=LEFT, R=RIGHT) AND BRAIN REGION. LOCATION OVER THE THREE AXES OF COORDINATES OF TALAIRACH SPACE. ACTIVATION GROUPS (CLUSTER) AND NUMBER OF VOXELS IN EACH ONE OF THEM. STATISTIC Z SCORE (Z).*

| **Condition Hemisphere / Region** | ***Talairach coordinates*** | | | ***Cluster*** | |
|---|---|---|---|---|---|
| | *x* | *y* | *z* | *Voxels* | *Z* |
| ***AB*** | | | | | |
| L / Middle temporal circumvolution | -66 | -35 | -18 | | 4.36 |
| L / Middle temporal circumvolution | -66 | -43 | -14 | 51 | 3.80 |
| L / Superior temporal circumvolution | -62 | -43 | 14 | | 3.56 |
| R / Middle temporal circumvolution | 68 | -39 | -14 | 28 | 4.04 |
| R / Cerebellum, anterior lobe | 7 | -43 | 2 | 12 | 3.58 |
| L / *Precuneus* | -13 | -55 | 34 | | 3.49 |
| R / *Precuneus* | 7 | -63 | 50 | 40 | 3.46 |
| L / *Precuneus* | -5 | -59 | 42 | | 3.39 |
| **CD** | | | | | |
| R / Superior frontal circumvolution | 11 | 54 | 34 | 21 | 3.36 |
| L / Precentral circumvolution | -37 | -19 | 66 | 9 | 3.13 |


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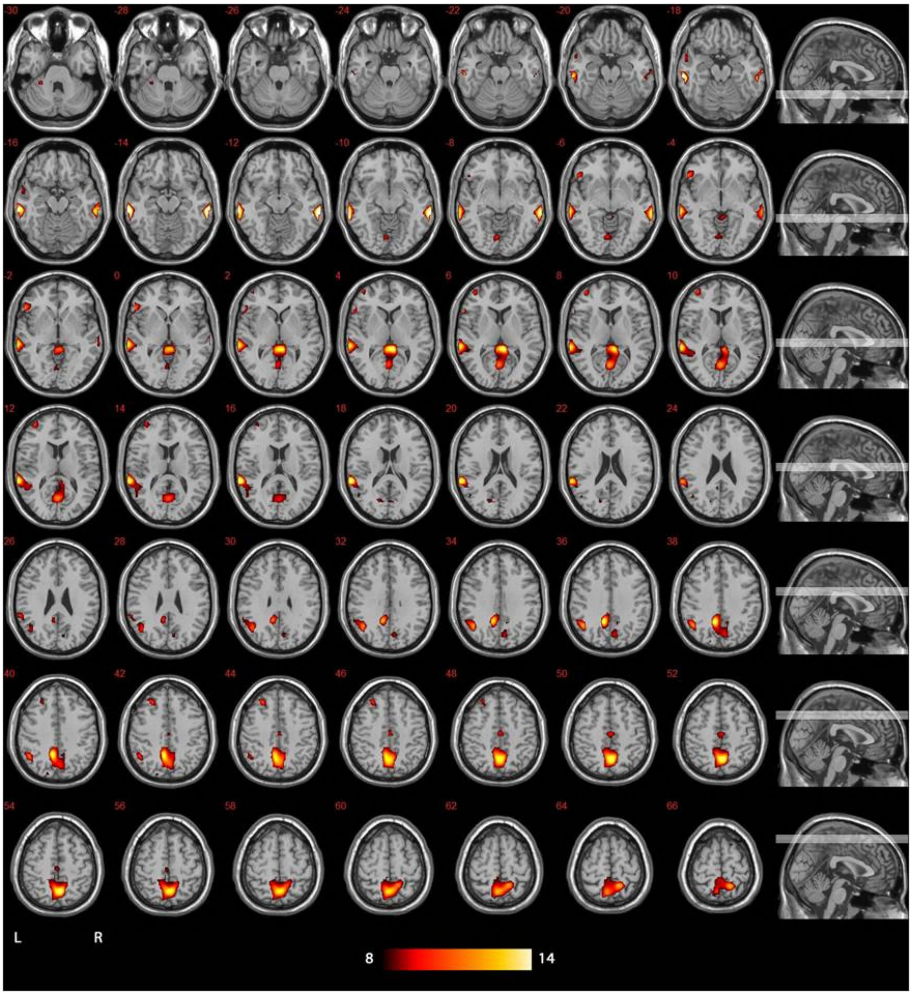


*Figure 2.* Statistical parametric maps for AB task – Neurological view (L=left, R=right). The right column (sagital view) indicates the position of the seven axial slices. Activation maps represent *Z* scores from 8 (black-red) to 14 (yellow-white).[1]

[1] *Note.* Original colored images can be found on the original paper at the journal's webpage http://revistes.ub.edu/index.php/Anuario-psicologia/index


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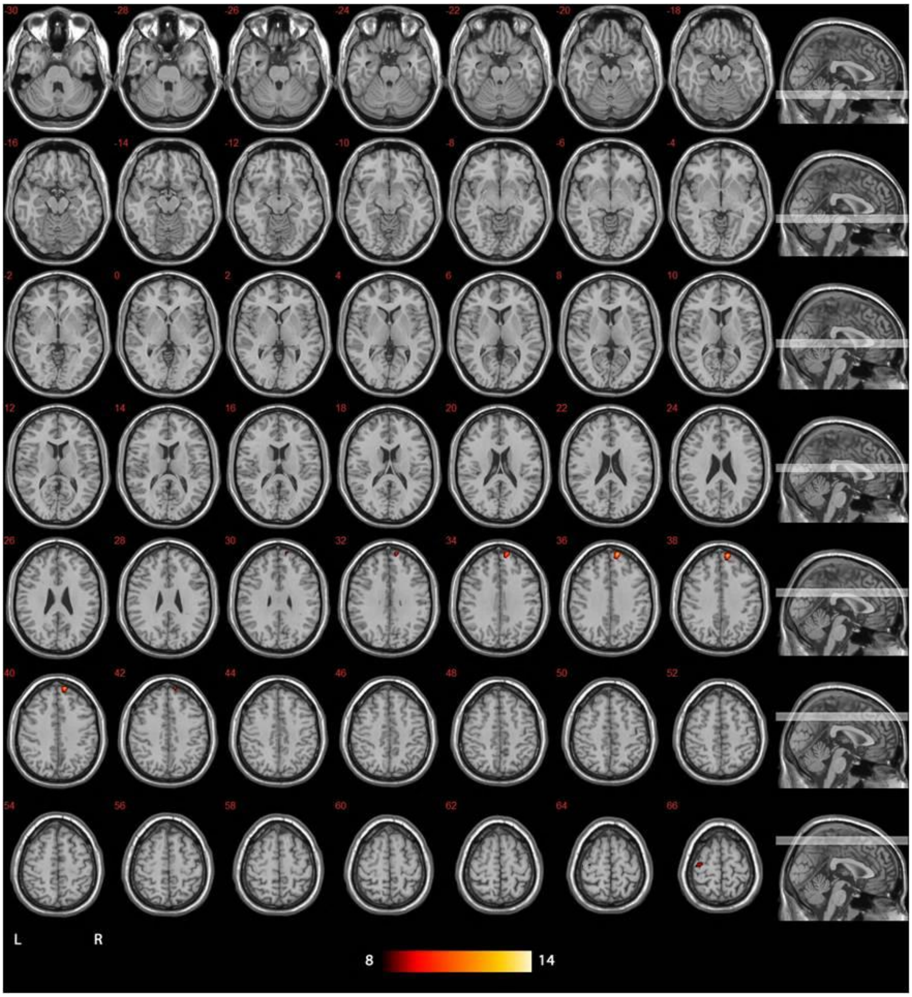


*Figure 3.* Statistical parametric maps for CD task – Neurological view (L=left, R=right). The right column (sagital view) indicates the position of the seven axial slices. Activation maps represent *Z* scores from 8 (black-red) to 14 (yellow-white).

## Conclusions

Taking together, the behavioral results suggest that the presence of spelling errors in words adds further complexity to the task when the participants have to detect this error (Blocks AB), but it fades when participants are asked to find a


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single letter, even though similar stimuli were used (Blocks CD). The present results suggest that learning processes involved in word representation (orthographic structure, phonology, semantics, etc.) have not yet been fully automated in the experimental group.

As noted in other studies, subjects with lower performance on tasks involving spelling and phonological conversion (e.g., detection of homophonic misspellings) usually show activation in different regions of temporal lobe, particularly the bilateral medial temporal circumvolution and the upper left temporal circumvolution. These results could be reflecting a higher cognitive effort of lower performers to succeed the task, probably involving wider regions on both hemispheres.

The present results did not show any significant frontal or inferior frontal activation, as it has been reported in other studies (Gebauer et al., 2012). This might be due to the fact that the task-difficulty level in the experimental tasks was limited, thus preventing further frontal involvement. Finally, a relevant activation was found at the posterior cingulate circumvolution and precuneus, which have been previously described in studies involving either attentional (Fransson & Marrelec, 2008) or memory retrieval (Maddock, Garrett, & Buonocore, 2001). In subjects with lower performance in orthographic tasks, this functional activation could be reflecting a difficulty to retrieve the mnesic representation of the word, or as an alternative, difficulty to sustain the attention enough to fulfill task demands.

When participants were instructed to detect a specific target letter in a word, there was a unilateral right frontal activation localized in the superior frontal circumvolution. It seems that this simpler task was not cognitively demanding probably because even though some words also contained orthographic errors, these participants did not invest resources to detect these types of mistakes. Their focus was on detecting the letter “i” regardless if the word was correctly spelled or not. Therefore, it could be expected that highly proficient readers have developed more specialized brain circuitry for the automatic detection of orthographic errors and thus even if instructed to only detect the letter “i”, it would be impossible for them not to simultaneously process if the word was well written. Hence suggesting it would be methodologically convenient to administer more complex tasks to highly skilled readers in future experimental designs.

Based on current findings, one could argue that even though both experimental tasks were similarly designed, both contained frequent and infrequent words as well as correct and incorrectly spelled words (homophone errors), the brain regions that exhibited greater demand of metabolic resources were different. The BOLD signal activations were distinct and bilateral activations were only observable in the active orthographic error detection task.

Altogether this suggest that different activation patterns correspond to the type of task being performed, with a clearly defined bilateral activation corresponding to A and B tasks and a more diffuse activation corresponding to C and


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D tasks. This differential activation pattern could be characteristic of individuals with poor reading proficiency. Until now, this orthographic transparency effect had not been identified in readers with low orthographic competence. It should be noted that the small sample size is a shortcoming when it comes to drawing conclusions and interpreting the results. The significant and sustained effects should be analyzed in sequence with more complex tasks and in a scanner with higher spatial resolution.

Furthermore, we consider it would be convenient to use these tasks with the objective of studying specific models that include behavioural measures and hemodynamic function in an event related experimental design with a longer stimulus exposure interval. Also convenient would be to study this phenomenon in experimental samples with different levels of orthographic competence, as well as reading speed and precision.

## REFERENCES

Bandettini, P.A., Kwong, K.K., Davis, T.L., Tootell, R.B.H., Wong, E.C., Fox, P.T., ..., Rosen, B.R. (1997). Characterization of cerebral blood oxygenation and flow changes during prolonged brain activation. *Human Brain Mapping*, *5*, 93-109.

Binder, J.R., Frost, J.A., Hammeke, T.A., Cox, R.W., Rao, S.M., & Prieto, T. (1997). Human brain language areas identified by functional Magnetic Resonance Imaging. *The Journal of Neuroscience*, *17*, 353-362.

Binder, J.R., & Price, C.J. (2006).Functional neuroimaging of language. In R. Cabeza & A. Kingstone (Eds.). *Handbook of functional neuroimaging of cognition, Second Edition.* (pp. 187-251). Massachusetts: MIT Press.

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.

Buxton, R.B. (2002). *Introduction to Functional Magnetic Resonance Imaging. Principles & Techniques*. New York: Cambridge University Press.

Cohen, L., Dehaene, S., Naccache, L., Lehéricy, S., Dehaene-Lambertz, G., Hénaff, M.A., & Michel, F. (2000). The visual word form area. Spatial and temporal characterization of an initial stage of reading in normal subjects and posterior split-brain patients. *Brain*, *123*, 291-307.

Cuetos, F., Gonzalez-Nosti, M., Barbón, A., & Brysbaert, M. (2011). SUBTLEX-ESP: Spanish word frequencies based on film subtitles. *Psicológica*, *32*, 133–143.

Dehaene, S., & Cohen, L. (2011). The unique role of the visual word form area in reading. *Trends in Cognitive Science*, *15*, 254-262.

Fiez, J.A. (1997). Phonology, semantics, and the role of the left inferior prefrontal cortex. *Human Brain Mapping*, *5*, 79-83.

Fransson, P., & Marrelec, G. (2008). The precuneus/posterior cingulate cortex plays a pivotal role in the default mode network: Evidence from a partial correlations network analysis. *Neuroimage*, *42*(3), 1178-1184.

Frost, R. (1994). Prelexical and postlexical strategies in reading: evidence from a deep and a shallow orthography. *Journal of Experimental Psychology Learning, Memory, and Cognition*, *20*(1), 116–129.


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Gabrieli, J.D.E., Poldrack, R.A., & Desmond, J.E. (1998). The role of left prefrontal cortex in language and memory. *Proceedings of the National Academy of Sciences, USA*, *95*, 906-913.
Gauthier, I., Tarr, M.J., Moylan, J., Skudlarski, P., Gore, J.C., & Anderson, A.W. (2000). The fusiform "face area" is part of a network that processes faces at the individual level. *Journal of Cognitive Neuroscience*, *12*, 495-504.
Gebauer, D., Enzinger, C., Kronbichler, M., Schurz, M., Reishofer, G., Koschutnig, K., …, Fink, A. (2012). Distinct patterns of brain function in children with isolated spelling impairment: New insights. *Neuropsychologia*, *50*, 1353-1361.
Gómez-Velázquez, F.R., González-Garrido, A.A., Zarabozo, D., & Amano, M. (2010). La velocidad de denominación de letras. El mejor predictor temprano del desarrollo lector en español. *Revista Mexicana de Investigación Educativa*, *15*, 823-847.
Gómez-Velázquez, F.R., González-Garrido, A.A., Guàrdia-Olmos, J., Peró-Cebollero, M., Zarabozo-Hurtado, D., & Zarabozo, D. (2014). Evaluación del conocimiento ortográfico en adultos jóvenes y su relación con la lectura [*Orthographic knowledge evaluation in young adults and its relationship with reading*]. *Revista Neurología, Neuropsiquiatría y Neurociencias*, *14*, 40-67.
González-Garrido A.A., Gómez-Velázquez F.R., & Rodríguez-Santillán E. (2014). Orthographic recognition in late adolescents. An assessment through event-related brain potentials. *Clinical EEG and Neuroscience*, *45*(2), 113-121.
Haacke, E.M., Brown, R.W., Thompson, M.R., & Venkatesan, R. (1999). *Magnetic Resonance Imaging. Physical Principles and Sequence Design*. New York: Wiley-Liss.
Huettel, S.A., Song, A.W., & McCarthy, G. (2009). *Functional Magnetic Resonance Imaging, Second Edition*. Massachusetts: Sinauer Associates.
Kanwisher, N., Downing, P., Epstein, R., & Kourtzi, Z. (2006). Functional neuroimaging of visual recognition. In R. Cabeza and A. Kingstone (Eds.).*Handbook of functional neuroimaging of cognition, Second Edition.* (pp. 109-151). Massachusetts: MIT Press.
Kronbichler, M., Bergmann, J., Hutzler, F., Staffen, W., Mair, A., Ladurner, G., & Wimmer, H. (2007). Taxi vs. Taksi: On orthographic word recognition in the left ventral occipitotemporal cortex. *Journal of Cognitive Neuroscience*, *19*, 1584-1594.
Landerl, K., & Wimmer, H. (2008). Development of word reading fluency and spelling in a consistent orthography: An 8-year follow-up. *Journal of Educational Psychology*, *100*, 150-161.
Logothetis, N.K. (2002). The neural basis of the blood-oxygen-level-dependent functional magnetic resonance imaging signal. *Philosophical Transactions of the Royal Society B*, *357*, 1003-1037.
Logothetis, N.K., Pauls, J., Augath, M., Trinath, T., & Oeltermann, A. (2001).Neurophysiological investigation of the basis of the fMRI signal. *Nature*, *412*, 150-157.
López-Escribano, C. (2007). Evaluation of the double-deficit hypothesis subtype classification of readers in Spanish. *Journal of Learning Disabilities*, *40*, 319-330.
Maddock, R.J., Garrett, A.S., & Buonocore, M.H. (2001). Remembering familiar people: the posterior cingulate cortex and autobiographical memory retrieval. *Neuroscience*, *104*(3), 667-676.
Marslen-Wilson, W.D., & Tyler, L.K. (2007). Morphology, language and the brain: the decompositional substrate for language comprehension. *Philosophical Transactions of the Royal Society B*, *362*, 823-836.
Nakamura, K., Kuo, J., Pegado, F., Cohen, L., Tzeng, O.J., & Dehaene, S. (2012). Universal brain systems for recognizing word shapes and handwriting gestures duringreading.*Proceedings of the National Academy of Sciences, USA*, *109,* 20762-20767.
Ogawa, S., Lee, T.M., Kay, A.R., & Tank, D.W. (1990). Brain magnetic resonance imaging with contrast dependent on blood oxygenation. *Proceedings of the National Academy of Sciences, USA*, *87*, 9868-9872.
Oldfield, R.C. (1971). The assessment and analysis of handedness: the Edinburgh Inventory. *Neuropsychologia*, *9*, 97-113.


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Paulesu, E., McCrory, E., Fazio, F., Menoncello, L., Brunswick, N., Cappa, S. F., … Frith, U. (2000). A cultural effect on brain function. *Nature Neuroscience*, *3*(1), 91–96.

Pugh, K.R., Mencl, W.E., Shaywitz, B.A., Shaywitz, S.E., Fulbright, R.K., Constable, R., ..., Gore, J.C. (2000). The angular gyrus in development dyslexia: Task-specific differences in functional connectivity within posterior cortex. *Psychological Science*, *11*, 51-56.

Schlaggar, B.L., & McCandliss, B.D. (2007). Development of neural systems for reading. *Annual Review of Neuroscience, 30,* 475-503.

Sebastián, N., Martí, M.A., Carreiras, M.F., & Cuetos, F. (2000). *LEXESP. Léxico informatizado del español*. Barcelona: Edicions de la Universitat de Barcelona.

Serrano, F., & Defior, S. (2008). Dyslexia speed problems in a transparent orthography. *Annals of Dyslexia*, *58*, 81-95.

Shaywitz, S.E., & Shaywitz, B.A. (2005). Dyslexia (specific reading disability). *Biological Psychiatry*, *57*, 1301-1309.

Vendrell, P., Junqué, C., & Pujol, J. (1995). La Resonancia Magnética funcional: una nueva técnica para el estudio de las bases cerebrales de los procesos cognitivos. *Psicothema*, *7*, 51-60.

Woodhead, Z.V.J., Brownsett, S.L.E., Dhanjal, N.S., Beckmann, C., & Wise, J.S. (2011). The visual word form system in context. *The Journal of Neuroscience*, *31*, 193-199.

Xue, G., & Poldrack, R.A. (2007). The neural substrates of visual perceptual learning of words: Implications for the visual word form area hypothesis. *Journal of Cognitive Neuroscience*, *19*, 1643-1655.

Ziegler, J. C., Perry, C., Jacobs, A. M., & Braun, M. (2001). Identical words are read differently in different languages. *Psychological Science*, *12*(5), 379–384.


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P.V.P.: 14€ (I.V.A. incluido)

ISSN 1988-5253
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ISSN 00665126
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