Commentary

DOI: 10.1177/0956797615569890

[1]Basque Center on Cognition, Brain and Language, Donostia, Spain; [2]Ikerbasque, Basque Foundation for Science, Bilbao, Spain; and [3]Department of Basque Language and Communication, University of the Basque Country

Corresponding Author:

Jon Andoni Duñabeitia, Basque Center on Cognition, Brain and Language, Paseo Mikeletegi 69, 2nd Floor, 20009 Donostia, Spain

E-mail: j.dunabeitia@bcbl.eu

The Impact of Literacy on Position Uncertainty

Jon Andoni Duñabeitia[1], Marie Lallier[1], Pedro M. Paz-Alonso[1], and Manuel Carreiras[1,2,3]

Received 1/2/15; Accepted 1/8/15

1. Focusing the debate

In a recent study exploring how literacy modulates perceptual matching abilities for character strings that include transposed and replaced characters, Duñabeitia, Orihuela, and Carreiras (2014) demonstrated that illiterates (a) showed a complete absence of transposed-character effects and (b) were unable to successfully identify individual characters embedded within strings. In their Commentary on this study, Perea, Winskel, Abu Mallouh, Barnes, and Gomez (2015) suggest that this lack of effects "had nothing to do with literacy acquisition per se but rather with the acquisition of orthographic representations." They refer to previous results from Perea, Abu Mallouh, García-Orza, and Carreiras (2011) and from García-Orza, Perea, and Muñoz (2010) showing that literates with no previous knowledge of a script failed to reveal masked-transposed-letter priming effects for character strings in that script, and that literate adults did not show the same effects for pseudoletter strings as for letter, symbol, or digit strings. Hence, Perea et al. argue that orthographic representations (and not literacy) were responsible for the emergence of transposed-character effects.

Leaving aside the fact that symbols and digits are clearly not orthographic units yet still elicit transposed-character effects, the existence of such effects for known but not for unknown characters could tentatively favor experience-based explanations for them, but it says nothing about their etiology. Furthermore, it is worth noting that these studies used the masked-priming version of the same/different task, which has been shown to be insensitive to critical differences in transposed-character effects for known visual elements. In the classic (unprimed) version of the same/different task, which was also used in Duñabeitia et al. (2014), transposition effects are significantly different for letters, digits, and symbols (see Duñabeitia, Dimitropoulou, Grainger, Hernández, & Carreiras, 2012; Massol, Duñabeitia, Carreiras, & Grainger, 2013).

More convincingly, Perea et al. present data from two unprimed same/different experiments demonstrating that literate adults showed small, yet significant, transposed-character effects for visual materials for which they lacked orthographic representations (Australian readers tested with Thai characters and Spanish readers tested with Devanāgarī characters). Accordingly, the researchers suggest that the results presented by Duñabeitia et al. (2014) for illiterates "could have been due to lack of power to detect a small-sized effect . . . combined with near-chance error rate." However, it should not be ignored that all the participants tested by Perea et al. were literates, whereas the evidence from the study by Duñabeitia et al. came from a group of illiterates. Hence, Duñabeitia et al.'s claim that "the skills related to the processing of internal characters' identities and positions are inherently dependent on literacy" (p. 1279) cannot be discarded on the basis of Perea et al.'s data.

2. New experimental evidence

The acquisition of orthographic representations is just one of the many cognitive consequences of literacy, and it is unlikely that Perea et al.'s participants inhibited all their literate skills to the point of becoming "illiterate" when confronted with an unknown script. The formation of an orthographic lexicon is the end point of literacy acquisition, but it primarily relies on the acquisition of higher-order linguistic representations and probabilistic self-teaching mechanisms (Carreiras, Armstrong, Perea, & Frost, 2014; Ziegler, Perry, & Zorzi, 2014). We argue that the lack of these representations and mechanisms (and not only the lack of orthographic representations) is what contributed to Duñabeitia et al.'s (2014) results.

To reinforce our position, we conducted a 3-year longitudinal study in which we tested a group of 34 children on a same/different task with consonant strings that included identical reference-target pairs (e.g., "rzsk"-"rzsk"), pairs created by transposing the two internal letters of the strings (e.g., "rzsk"-"rszk"), and pairs created by replacing those two letters (e.g., "rzsk"-"rhck"; for details, see the Supplemental Material available online). The same children were tested three times: twice when they were preliterates (during their penultimate and last preschool year) and once again when they had been formally taught to read and write (at the end of the first year of elementary school, when they were neoliterates). Results unambiguously demonstrated that significant transposed-character effects emerged only after these children had acquired basic literacy skills (a significant 12% effect in elementary school vs. the negligible −3.5% and 4% effects in preschool assessments when contrasting the transposed and replaced-character conditions). These results strongly support Duñabeitia et al.'s (2014) results for illiterates suggesting that position uncertainty emerges as a consequence of literacy training and, possibly, of self-teaching mechanisms underlying letter-position coding.

The data from this longitudinal study also strengthen the second conclusion that can be drawn from Duñabeitia et al. (2014): that preliterate children (like illiterate adults) are unable to successfully identify individual characters embedded within strings when confronted with positional changes. Thus, mechanisms for coding the within-string position and identity of characters are the direct consequence of literacy. In the two initial assessments of the 3-year study, preliterates performed at chance level in both *different* conditions, unlike in the *same* condition (see also *d*′ scores in the Supplementary Material), and it was only when these children acquired literacy skills that they showed significant improvement in the replaced-character condition, leading to the observed transposed-character effects in elementary school.

Finally, we agree with Perea et al. (2015) that "one of the effects of literacy is the emergence of letters (from a known alphabet) as distinct objects that might be explicitly coded by populations of neurons." In fact, this is precisely what Duñabeitia et al. (2014) suggested by stating that "transposed-character effects are the consequence of the letter-specific visual coding mechanisms that develop during reading acquisition" (p. 1279). As recently shown in a functional MRI study using the perceptual matching task with transposed and replaced characters by Carreiras, Quiñones, Hernández-Cabrera, and Duñabeitia (2014), there are stimulus-specific neural mechanisms for letter-position coding rooted in the left parietal cortex, and these mechanisms clearly diverge from those associated with the coding of positions of other stimuli.

3. Final remarks

It remains to be seen to what extent particular tunings of parameters of existing models of orthographic coding based on a priori letter-unspecific position-uncertainty principles can account for the behavioral, temporal, and neural differences underlying letter-sensitive transposition effects, their emergence, and their development (e.g., Gomez, Ratcliff, & Perea, 2008). It's still to be demonstrated how the failure to obtain transposition effects with unknown characters (e.g., García-Orza et al., 2010) could be explained by models based on object-unspecific theories of visual spatial attention.

Author Contributions

J. A. Duñabeitia and M. Carreiras developed the study concept. All authors contributed to the study design. Testing and data collection were performed by trained research assistants under the supervision of all authors. J. A. Duñabeitia and M. Carreiras drafted the manuscript, and all authors provided critical revisions. All authors approved the final version of the manuscript for submission.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Funding

This study was partially supported by Grants PSI2012-32123, PSI2012-32128, PSI2012-32093, and PSI2012-31448 from the Spanish Government; by Grant ERC-2011-ADG-295362 from the European Research Council; and by Grant 613465 from the AThEME project, funded by the European Union Seventh Framework Programme.

Supplemental Material

Additional supporting information can be found at http://pss.sagepub.com/content/by/supplemental-data

References

Carreiras, M., Armstrong, B. C., Perea, M., & Frost, R. (2014). The what, when, where, and how of visual word recognition. *Trends in Cognitive Sciences, 18*, 90–98. doi:10.1016/j.tics.2013.11.005

Carreiras, M., Quiñones, I., Hernández-Cabrera, J. A., & Duñabeitia, J. A. (2014). Orthographic coding: Brain activation for letters, symbols and digits. *Cerebral Cortex*. Advance online publication. doi:10.1093/cercor/bhu163[

Duñabeitia, J. A., Dimitropoulou, M., Grainger, J., Hernández, J. A., & Carreiras, M. (2012). Differential sensitivity of letters, numbers and symbols to character transpositions. *Journal of Cognitive Neuroscience, 24*, 1610–1624. doi:10.1162/jocn_a_00180

Duñabeitia, J. A., Orihuela, K., & Carreiras, M. (2014). Orthographic coding in illiterates and literates. *Psychological Science, 25*, 1275–1280. doi:10.1177/0956797614531026

García-Orza, J., Perea, M., & Muñoz, S. (2010). Are transposition effects specific to letters? *Quarterly Journal of Experimental Psychology, 63*, 1603–1618. doi:10.1080/17470210903474278

Gomez, P., Ratcliff, R., & Perea, M. (2008). The overlap model: A model of letter position coding. *Psychological Review, 115*, 577–601. doi:10.1037/a0012667

Massol, S., Duñabeitia, J. A., Carreiras, M., & Grainger, J. (2013). Evidence for letter-specific position coding mechanisms. *PLoS ONE, 8*(7), Article e68460. Retrieved from http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0068460

Perea, M., Abu Mallouh, R., García-Orza, J., & Carreiras, M. (2011). Masked priming effects are modulated by expertise in the script. *Quarterly Journal of Experimental Psychology, 64* (5), 902–919.

Perea, M., Winskel, H., Abu Mallouh, R., Barnes, L., & Gomez, P. (2015). In defense of position uncertainty: A reply to Duñabeitia, Orihuela, and Carreiras (2014). *Psychological Science, 26*, xxx–xxx.

Ziegler, J. C., Perry, C., & Zorzi, M. (2014). Modelling reading development through phonological decoding and self-teaching: Implications for dyslexia. *Philosophical Transactions of the Royal Society B: Biological Sciences, 369*, 20120397. doi:10.1098/rstb.2012.0397

SOM-R Supplementary Materials

Experiment

Methods

Participants. 34 Basque children (11 girls) from two different Basque schools completed the three different phases of this experiment. The first phase of the experiment was completed during the antepenultimate pre-school academic year, when the children had a mean age of 4.24 years (SD=0.43). The second phase of the experiment was completed during the last pre-school year, when the same children had a mean age of 5.21 years (SD=0.41). The third phase of the experiment was completed at the end of the first academic year of elementary school, when these children had a mean age of 6.32 years (SD=0.47) and had already acquired literacy skills. None of the participants had any specific developmental, psychological, psychiatric or educational disorder or deficit. Informed parental consent was obtained from each child prior to each experimental phase.

Materials. In each experimental phase pairs of identical and different letter strings made of 4 consonants (40 pairs in the "same" condition and 40 pairs in the "different" conditions) were used in the *same-different perceptual matching task*. In the set of "same" trials, targets were exact repetitions of references (e.g., rzsk-rzsk). Within the set of "different" trials, 20 pairs corresponded to the transposed-character condition (e.g., rzsk-rszk) and 20 pairs corresponded to the replaced-character condition (e.g., rzsk-rhck). Two lists were constructed for counterbalancing purposes. The presentation of the items was randomized for each participant in each experimental phase.

Procedure. Participants were tested individually in their schools and the same technological equipment was used in each of the three data collections (same PCs and same peripherals). The experiment was run using Presentation software. Stimuli were presented on a computer screen at a distance of approximately 70 cm (1024x768 resolution, 90Hz), in white Courier New font on a black background. Each trial started with the presentation of a fixation cue (·) in the center of the screen for 500ms. Next, the reference stimulus was presented for 1000ms, horizontally in the center of the screen. This reference was immediately replaced by a mask (####) for 500ms. After the mask, the target was displayed in the center of the screen for a maximum of 5000ms or until response. The ISI was set to 1000ms. Participants were instructed to press one of two buttons on a keyboard when the two strings were identical and the other when they were different. Participants were asked to respond as accurately as possible once the target had appeared on the screen, with no time pressure. Instructions were verbally recorded so that every child received the same input, and the experimenter made sure that participants had understood the instructions by completing a short practice session with them.

Results

ANOVAs were run on the error rates in the “different” responses following a 2x3 design (Condition: transposed|replaced; Phase: 1|2|3). Mean error rates for each condition and in each phase are presented in the Figure and in the

Table. The main effect of Condition was significant, showing that items in the transposed-characters condition elicited significantly more errors than items in the replaced-characters condition [$F1(1,33)=4.40$, $p=.044$, $\eta^2_{partial}=.12$; $F2(1,19)=7.50$, p=.013, $\eta^2_{partial}$=.28]. The main effect of Phase was also significant, showing that the error rates decreased as an inverse function of age [F1(2,66)=11.00, p<.001, $\eta^2_{partial}$=.25; F2(2,38)=55.01, p<.001, $\eta^2_{partial}$=.74]. Critically, the interaction between the two factors was significant, demonstrating that the transposed-character effect varied across the different test phases [F1(2,66)=6.95, p=.002, $\eta^2_{partial}$=.17; F2(2,38)=8.72, p=.001, $\eta^2_{partial}$=.31].

A series of pairwise comparisons (t-tests) were run in order to explore the significance of this interaction, and results showed that the difference in error rates between the transposed-characters and the replaced-characters conditions (namely, the transposed-character effect) was significant only in the third test phase, when children had already acquired basic reading skills [Phase 1: t1(33)=1.19, p=.243; t2(19)=1.29, p=.211; Phase 2: t1(33)=1.31, p=.200; t2(19)=1.65, p=.115; Phase 3: t1(33)=3.63, p=.001; t2(19)=4.57, p<.001].

A series of ANOVAs were also run in order to investigate the differences in the error rates associated with the "same" responses in the three different test phases. Results showed a main a effect of Phase [F1(2,66)=16.67, p<.001, $\eta^2_{partial}$=.34; F2(2,78)=156.13, p<.001, $\eta^2_{partial}$=.80], and pairwise comparisons demonstrated that error rates in the "same" conditions were relatively similar in the first and the second phases [t1(33)=.52, p=.609; t2(39)=1.97, p=.055], whereas performance in the third phase was significantly better than in the two previous phases [all ts>5 and ps<.001].

Children's discriminability indices (d') were also obtained, and a participants-based ANOVA was run including the factor Phase (1|2|3). The discriminability indices were different across phases [F(2,66)=58.89, p<.001, $\eta^2_{partial}$=.64], showing that participants completed the task significantly better in the second than in the first phase [t(33)=3.13, p=.004], and in the third than in the second phase [t(33)=7.88, p<.001]. Furthermore, a series of pairwise comparisons demonstrated that while children did not show d' indices different from 0 in the first phase, their d' scores were significantly higher than 0 in the second and in the third phases [Phase 1: t(33)=1.54, p=.133; Phase 2: t(33)=3.65, p=.001; Phase 3: t(33)=11.13, p<.001].

Table. Mean error rates (percentage) and standard deviations in each condition and test phase, together with the transposed-character effects (mean error rate in the transposed-characters conditions minus mean error rate in the replaced-characters conditions), and d-prime (d') indices of discriminability.

	Test phase		
	Phase 1	Phase 2	Phase 3
Same	39.29% (19.86)	36.76% (19.93)	17.28% (13.03)
Transposed-characters	55.90% (21.74)	48.03% (21.47)	42.94% (19.47)
Replaced-characters	59.40% (20.11)	43.68% (22.06)	30.61% (21.47)
Effect	-3.50%	4.35%	12.33%
d'	0.12 (0.47)	0.51 (0.82)	1.47 (0.77)

Figure. Mean error rates in each condition and each test phase. Error bars represent 95% confidence intervals.