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Serial mechanism in transposed letters effects: A developmental study

Lucia Colombo [a,*], Simone Sulpizio [b,c], Francesca Peressotti [d]

[a] *Dipartimento di Psicologia Generale, Università di Padova, 35131 Padova, Italy*
[b] *Facoltà di Psicologia, Università Vita-Salute San Raffaele, 20132 Milano, Italy*
[c] *Fondazione Marica De Vincenzi ONLUS, 38068 Rovereto, Italy*
[d] *Dipartimento di Sviluppo e Socializzazione, Università di Padova, 35131 Padova, Italy*

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ABSTRACT

The study describes the developmental trend of transposed letters (TL) effects in a lexical decision task. The TL effect refers to the fact that nonwords derived from words by transposing two middle letters (e.g., *talbe* from *table*) are responded to more slowly than control nonwords in which two letters are replaced (RL [replaced letters]; e.g., *tafde*). We measured this effect in three groups of children (second, third, and fifth graders) and a group of adults. Length was manipulated with short letter strings (four or five letters) and long letter strings (seven or eight letters). In long letter strings, position of letter transposition/replacement was also manipulated; half of the stimuli contained the TL/RL toward the beginning of the string and half toward the end of the string. The results showed that the size of the TL effect increased with age and that this developmental pattern was more marked for transpositions involving the final part of the word. The results suggest that with the increase in reading ability, the reading system relies more strongly on a coarse orthographic representation in which letter position is not precisely coded. Furthermore, the effect of position suggests that a serial mechanism is used to scan the letter string. This determines the extent to which nonwords activate the base words, modulating the influence of lexical effects in nonword decisions. The nature of this effect is discussed.

* Corresponding author.
E-mail address: lucia.colombo@unipd.it (L. Colombo).

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Introduction

Transposition of adjacent or nonadjacent letters within words can create nonwords that are often misperceived as real words even by expert adult readers. The result is the so-called transposed letters (TL) effect, which consists in a delay in rejecting a transposed letter nonword compared with a control nonword (e.g., in a lexical decision task). This effect has been ascribed to a fast visual–orthographic process that recognizes words considering the global letter pattern independently of the identity and position of each single letter (e.g., Grainger, Lété, Bertand, Dufau, & Ziegler, 2012). An intriguing question is how this process develops during the first steps of reading acquisition. We provide an answer to this question by tracking the changes of the letter transposition effect during reading development.

The literature on TL effects has shown that words in which adjacent or nonadjacent letters are exchanged (e.g., trial–trail) are more difficult to process than control words (e.g., train) in both lexical decision and naming (Andrews, 1996; Chambers, 1979; Perea & Fraga, 2006; Perea, Rosa, & Gómez, 2005). Other evidence on TL effects has been provided with the priming paradigm, in which a target word is preceded by a briefly presented prime nonword sharing all letters with the target word but with a letter exchange (e.g., jugde–JUDGE). In lexical decision, this TL condition produces facilitation compared with a control condition (junpe–JUDGE) in which two letters are replaced rather than transposed (Forster, Davis, Schoknecht, & Carter, 1987; Perea & Lupker, 2003a, 2003b; Schoonbaert & Grainger, 2004). The priming effect also occurs when the TL prime is semantically related, not form related, to the target, as in the example jugde–COURT, suggesting that TL nonwords activate the lexical–semantic representation of the target.

TL effects suggest a flexible coding of letter position. However, this is in contrast to early computational models of visual word recognition such as the interactive activation model (McClelland & Rumelhart, 1981; Rumelhart & McClelland, 1982), the dual-route cascaded model (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001), the multiple readout model (Grainger & Jacobs, 1996), and the connectionist dual process (CDP+) model (Perry, Ziegler, & Zorzi, 2007) and connectionist models (Plaut, McClelland, Seidenberg, & Patterson, 1996; Seidenberg & McClelland, 1989), because all of them assume that in word recognition each letter of a string is coded in a given absolute position according to a slot-based schema.

Several models have been proposed to deal with TL effects, suggesting different solutions to position coding (the self-organizing lexical acquisition and recognition [SOLAR] model: Davis, 1999, 2010; the overlap model: Gomez, Ratcliff, & Perea, 2008; the open-bigram model: Grainger & van Heuven, 2003; the sequential encoding regulated by inputs to oscillations within letter units [SERIOL] model: Whitney, 2001). In the current study, we focused primarily on the multiple-routes account of word recognition proposed by Grainger and collaborators (Grainger & Ziegler, 2011; Grainger et al., 2012; Ziegler, Bertrand, Lété, & Grainger, 2014) and its specific developmental predictions. The multiple-routes model focuses on the mapping from orthography to semantics, assuming that in orthographic processing two different types of orthographic codes are formed, both working in parallel (Grainger & Ziegler, 2011; Grainger et al., 2012). The first type of orthographic code is the output of a coarse-grained mechanism that activates lexical orthographic representations through letter combinations that do not specify letter position, so-called open bigrams. For instance, in reading the word *table*, the bigrams TA, TB, TL, TE, AB, AL, AE, BL, BE, and LE are open bigrams activated by the coarse-grained mechanism. The second type of orthographic code is the output of a mechanism providing precise information about the order of letters in the string. This mechanism codes letters into multi-letter grapheme units (as, e.g., higher order sublexical units such as graphemes, affixes, and other frequently co-occurring letter clusters), which in turn activate the corresponding phonemes. Whereas the coarse-grained code is computed taking into account all the letters of a string in parallel, the fine-grained code is computed more serially, beginning from the first letters of the string. By means of these two types of orthographic codes, the model may account for both the flexible coding that is reflected in phenomena like the TL effects and the successful operation of sublexical orthography–phonology conversion, which requires a precise coding of letter positions.