Journal of Memory and Language 68 (2013) 85–97

Contents lists available at SciVerse ScienceDirect

Journal of Memory and Language

journal homepage: www.elsevier.com/locate/jml

The role of orthographic syllable structure in assigning letters to their position in visual word recognition

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ARTICLE INFO

Article history:
Received 11 January 2012
revision received 17 October 2012
Available online 17 November 2012

Keywords:
Lexical processing
Visual word recognition
Letter transposition
Orthographic processing
Syllable structure
Letter position

ABSTRACT

The way in which letters are assigned their position when recognizing a visually presented word was examined in three experiments using nonwords created by transposing the two medial consonants of a bisyllabic baseword (e.g., *nakpin*, *semron*). The difficulty in responding to such "TL" nonwords in a lexical decision task was shown to be lower when the medial consonants of the baseword formed a complex coda (e.g., the *rm* of *sermon*) than when they comprised a separate coda and onset (e.g., the *p* and *k* of *napkin*). The same result was shown in false positive responses to nonwords when their visibility was degraded through masking. In addition, these TL effects were just as strong for nonwords like *nakpin* as they were for nonwords whose medial consonants formed a complex coda like *warlus*, but whose baseword was syllabified between those consonants (e.g., the *l* and *r* of *walrus*). Such findings are a challenge for most current models of letter position assignment. Instead, they can be explained by an account where bisyllabic words are stored in lexical memory with a structure that maximizes the coda of the first syllable and where medial consonants are tried out in all viable subsyllabic slots.

Introduction

In order to recognize a visually presented word, it is necessary to ensure that its component letters are assigned to their appropriate position so that the mental representation of that word can be activated. Given the well-established finding that a word can be easily recognized even when two of its letters have been transposed, it is apparent that the assigned position for a letter need not correspond exactly to its position in the presented letter-string. This is especially true for medial letters given that their transposition (as in *nakpin* for example) is generally less disruptive to recognition of the baseword (*napkin*) than are transpositions involving initial or final letters (e.g., *anpkin* or *napkni* respectively: e.g., Bruner & O'Dowd, 1958; Chambers, 1979; Perea & Lupker, 2003; Taft & Nillsen, 2012; White, Johnson, Liversedge, & Rayner, 2008).

Different experimental paradigms have been used to demonstrate the ease of activating a word despite its transposed letters. For example, lexical decisions to a nonword are harder when it creates a real word through letter transposition (e.g., *nakpin*) relative to a nonword (such as *naktin*) that does not (e.g., Andrews, 1996; Chambers, 1979; Frankish & Turner, 2007; Lee & Taft, 2009; O'Connor & Forster, 1981; Perea & Carreiras, 2006; Perea & Lupker, 2004; Taft & Nillsen, 2012). This transposed-letter ("TL") interference effect indicates that the baseword was successfully activated even though not all of its letters were in their correct position, and such lexical activation makes it hard to classify the stimulus as a nonword. Another approach (e.g., Forster, Davis, Schoknecht, & Carter, 1987; Lupker, Perea, & Davis, 2008; Perea & Lupker, 2004; Schoonbaert & Grainger, 2004) has been to show that recognition of the (uppercase) base word (e.g., *NAPKIN*) is facilitated by the prior masked (lowercase) presentation

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http://dx.doi.org/10.1016/j.jml.2012.10.004

of its TL version (e.g., *nakpin*) relative to the different-letter control (e.g., *naktin*).

These TL effects are important for our understanding of reading because they provide a window into the way in which information about letter position is used to make contact with stored lexical representations. There are several different approaches that have been taken in relation to this issue. First, there are models of word recognition that incorporate a sublexical level of processing whereby a word is activated via a set of "open" bigrams (e.g., Grainger & van Heuven, 2003; Grainger & Whitney, 2004; Schoonbaert & Grainger, 2004; Whitney, 2001; Whitney & Cornelissen, 2005, 2008). These are all the adjacent and non-adjacent pairs of letters found within the word in their specific order (e.g., *fl*, *fa*, *fp*, *la*, *lp*, and *ap* in *flap*). A TL nonword activates its baseword by virtue of the fact that most of their open bigrams overlap. For example, the TL nonword *falp* activates all the bigrams corresponding to the baseword *flap* except for *la*.

Davis (2010) presents an alternative spatial coding account of letter position coding (see also Davis, 2006; Davis & Bowers, 2004, 2006) where the lexical representation for each word is sensitive to a particular pattern of activation for its component letters, reflecting their relative position. So, the lexical representation for *flap* will be most responsive to a pattern of activation where *f* is activated more strongly than *l*, which is activated more strongly than *a*, which in turn is activated more strongly than *p*. When the TL nonword *falp* is presented, the level of activation for *f* and *p* is as expected for the word *flap*, while that of *a* and *l* is not very different to the expected pattern. Hence, the baseword is strongly activated and TL effects emerge.

Another approach incorporates an imprecise assignment of letters to their positional slots (e.g., Gómez, Ratcliff, & Perea, 2008; Norris, Kinoshita, & van Casteren, 2010). While the lexical representation for *flap* might be most strongly activated by the presence of *l* in the second letter-slot, it will nevertheless receive some activation from its presence in the third letter-slot, and vice versa for the letter *a*. In this way, the TL nonword *falp* will activate the lexical representation for its baseword *flap* despite the re-ordering of its medial letters.

All of the above accounts of word recognition have assumed that the only sublexical structure to play a role in orthographic processing is at the level of the single letter or bigram. However, a word is more than just a concatenation of letters or an overlapping set of bigrams. For a start, some letters function as vowels and some as consonants and there is evidence from TL manipulations that these two types of letter are processed differently in relation to the assignment of their position in the word. Perea and Lupker (2004) demonstrated stronger effects in both TL priming and TL interference for transposed consonants (e.g., *caniso* derived from the baseword *casino*) than for transposed vowels (e.g., *cisano*) and concluded that vowels must be discriminated from consonants at a very early stage of orthographic processing (cf. Berent & Perfetti, 1995). The models of orthographic processing described above have not incorporated any distinction between vowels and consonants, and Perea and Lupker (2004) make suggestions as to how they might do so.

A further important distinction can also be drawn within the category of consonants. Within a syllable, some consonants come before the vowel (i.e., are "onsets") while others come after the vowel (i.e., are "codas"). For example, *flap* has *fl* as its onset and *p* as its coda. There is considerable evidence that onsets are treated separately from the rest of the syllable in reading English (e.g., Andrews & Scarratt, 1998; Kay & Marcel, 1981; Taft, 1992; Taraban & McClelland, 1987; Treiman & Chafetz, 1987), where the rest of the syllable (or "body") is composed of the vowel and coda if there is one (e.g., the *ap* of *flap*). Lee and Taft (2009) propose a model of lexical processing that incorporates such subsyllabic structure by having the stimulus letters initially assigned to slots corresponding to their status as onset, vowel, or coda. A lexical representation (e.g., *flap*) is activated via sublexical units that separately represent onsets (e.g., *fl*) and bodies (e.g., *ap*), with the latter being activated by the letters that are assigned to the vowel and coda slots (*a* and *p* respectively). In order that the letters be assigned to their appropriate slot, consonants and vowels must be discriminated at a very early stage, as suggested by Perea and Lupker (2004). The vowel is then assigned to its corresponding slot, but the task of determining the status of the consonants as onset or coda still remains. Within each slot there are multiple positions available and these need to be assigned appropriately as well. For example, the *f* of *fl* must be placed in the first position of the onset slot and *l* in the second position of that slot.

It is relatively easy to identify which consonant should be assigned to the first position of the onset slot and which consonant should be assigned to the final position of the coda slot because the blank space before and after the letter-string makes the physical location of the first and last letters highly salient. It is the consonants that do not occur in initial or final position that are the most difficult to assign. For example, there is ambiguity as to whether the *l* of *flap* should be assigned to the second position of the onset slot or the penultimate position of the coda slot. It is only when it is assigned to the former that the lexical representation for *flap* will be activated. The same ambiguity of assignment holds for the *l* of the nonword *falp*. So, when an attempt is made to try out this *l* in the onset slot, the lexical representation for *flap* will be activated, hence generating TL effects. Because there is far less difficulty in assigning initial or final letters than medial letters to their correct slot, transpositions involving medial letters will show the stronger TL effects (e.g., Bruner & O'Dowd, 1958; Chambers, 1979; Perea & Lupker, 2003; White et al., 2008). Nevertheless, a medial transposition can often be detected, so Lee and Taft (2009) propose the existence of a supplementary mechanism that more consciously identifies the position of the consonant relative to the vowel, and assigns that consonant to its correct onset or coda slot accordingly.

Lee and Taft (2009) supported their "ambiguous assignment" account by demonstrating that TL interference does not occur for medial transpositions when the status of the medial letters as onset or coda is unambiguous. Such a situation arises with the Korean Hangul script where onset and coda position are physically identifiable even when