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Competition between orthographically and phonologically similar words during sentence reading: Evidence from eye movements

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ABSTRACT

Two eye movement experiments tested the effect of orthographic and/or phonological overlap between prime and target words embedded in a sentence. In Experiment 1, four types of overlap were tested: phonological and orthographic overlap (O+P+) occurring word initially (*strain–strait*) or word finally (*wings–kings*), orthographic overlap alone (O+P−, *bear–gear*) and phonological overlap alone (O−P+, *smile–aisle*). Only O+P+ overlap resulted in inhibition, with the rhyming condition showing an immediate inhibition effect on the target word and the non-rhyming condition on the spillover region. No priming effects were found on any eye movement measure for the O+P− or the O−P+ conditions. Experiment 2 demonstrated that the size of this inhibition effect is affected by both the distance between the prime and target words and by syntactic structure. Inhibition was again observed when primes and targets appeared close together (approximately 3 words). In contrast, no inhibition was observed when the separation was nine words on average, with the prime and target either appearing in the same sentence or separated by a sentence break. However, when the target was delayed but still in the same sentence, the size of the inhibitory effect was affected by the participants' level of reading comprehension. Skilled comprehenders were more negatively impacted by related primes than less skilled comprehenders. This suggests that good readers keep lexical representations active across larger chunks of text, and that they discard this activation at the end of the sentence. This pattern of results is difficult to accommodate in existing competition or episodic memory models of priming.

Introduction

There is a great deal of evidence from studies of isolated word recognition that reading involves a process of competition between form-related words. Much of this evidence has come from the masked priming paradigm in which a prime word is presented for a very short time (below the threshold of conscious awareness) and a response, often a lexical decision, is made on a following target word (Forster & Davis, 1984; see also Kinoshita & Lupker, 2003). It has been found that when a target word is primed by an orthographic neighbor, i.e. a word that differs from it by only one letter (see Coltheart, Davelaar, Jonasson, & Besner, 1977), the response to the target word can be slowed, especially when the prime is of a higher frequency than the target (e.g. Davis & Lupker, 2006; Grainger, 1990; Grainger & Ferrand, 1994; Nakayama, Sears, & Lupker, 2008; Segui & Grainger, 1990). Our interest was in how these effects

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might influence processing in a more natural reading task, i.e. normal sentence reading. Fluent reading must require the constant activation and suppression of word candidates and success in this task may be related to one's level of reading skill (e.g. Andrews & Hersch, 2010; Andrews & Lo, 2012; Gernsbacher, 1993). However, very little research has investigated the effect of form overlap on lexical access during sentence reading (but see Paterson, Liversedge, & Davis, 2009). The experiments we report were designed to look for evidence of form-based competition between words in sentences. We examined whether different types of overlap, orthographic and/or phonological, resulted in different degrees of competition (Experiment 1), and whether the distance between the overlapping words and the syntactic structure they appear in affected the competition effect (Experiment 2). In addition, we examined whether the size of the competition effect was related to reading comprehension skill (Experiment 2).

A large body of research has now demonstrated that word reading processes are influenced by the availability of form-related words, although the nature of this influence remains an issue for debate (see Andrews, 1997, and Grainger, 2008, for reviews). Words with large orthographic neighborhoods can be processed more quickly than words with small neighborhoods in lexical decision and naming tasks (e.g. Andrews, 1989). However lexical decision can be slowed by the existence of a high-frequency orthographic neighbor (e.g. Grainger, O'Regan, Jacobs, & Segui, 1989) and by the presence of a high-frequency embedded word such as 'car' in 'scar' (Bowers, Davis, & Hanley, 2005, see also Weingartner, Juhasz, & Rayner, 2012, for evidence from eye movements). Indeed, what actually constitutes a neighborhood is also a matter for debate, with evidence of effects of neighborhoods that are defined in a number of different ways, including letter deletion (e.g. *last–blast*; Davis & Taft, 2005) transposed letters (e.g. *clam–calm*, Andrews, 1996), and phonological overlap (e.g. *soup–hoop,* Yates, Locker, & Simpson, 2004). In priming tasks, the shared neighborhoods of primes and targets have also been shown to affect processing speed (e.g. Van Heuven, Dijkstra, Grainger, & Schriefers, 2001).

As mentioned above, research using masked priming has shown that word recognition times are influenced by orthographic neighbor primes. High-frequency prime words (e.g. *wings*) slow responses to lower-frequency target words (e.g. *kings*), whereas orthographic neighboring nonwords (e.g. *fings*), speed up recognition of the same target word (e.g. Davis & Lupker, 2006; Grainger, 1990; Grainger & Ferrand, 1994; Nakayama, Sears, & Lupker, 2008; Segui & Grainger, 1990). These effects of lexicality and relative frequency have been accounted for by the proposal that form priming involves both facilitation from sublexical overlap and competition between lexical items (Davis & Lupker, 2006; Perry, Lupker, & Davis, 2008). Localist models of word recognition, such as McClelland and Rumelhart's (1981) interactive-activation model (IAM) simulate these effects with facilitatory links between letter and word levels and inhibitory links between words. The architecture of this model has formed the basis of other, more performance-based, models of word recognition, all of which propose that lexical retrieval involves a process of form-based lexical competition (e.g. the Multiple Read Out model, Grainger & Jacobs, 1996; the Dual Route Cascaded Model, Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; the Self Organising Lexical Access and Recognition Model, Davis, 1999; and the Bi-modal Interactive Activation model or BIAM, Grainger & Holcomb, 2009).

Masked form priming effects are also influenced by neighborhood size, such that facilitation from nonword primes is observed only for target words with low density neighborhoods (Andrews, 1997; Forster & Taft, 1994). This effect has been taken as evidence that the representations of words in high density neighborhoods are more precisely specified than those in low density neighborhoods, and therefore less likely to be activated by form-related primes (Forster & Taft, 1994; see also Perfetti, 1992). This proposal is supported by studies showing that the neigbourhood density effect is also modulated by individual differences in reading skill levels (Andrews & Hersch, 2010; Andrews & Lo, 2012), and we return to this issue in Experiment 2.

The results reviewed above provide clear evidence that isolated word recognition is affected by the existence and/or priming of formally similar words. Studies of similar effects in sentence reading are much more rare. Fast priming experiments, that have examined orthographic neighbor priming, show facilitation or null effects rather than inhibition (e.g. Nakayama, Sears, & Lupker, 2010). In this methodology, participants read normal text in which one word is initially presented as a random letter string. Once the participant "lands" on this target region, the random letters are replaced by the prime word for a very short period before being replaced again by the target word and eye fixation data are recorded (Sereno & Rayner, 1992). This paradigm is, therefore, very similar to masked priming, but it uses a more natural linguistic environment. Nakayama et al. (2010) tested orthographically overlapping items that had previously shown inhibition in a masked priming paradigm (Nakayama et al., 2008). At a prime duration of 60 ms, they found facilitation when prime and target were presented in lower-case (Experiment 1) and no difference when the prime was presented in capitals. Similarly, Frisson, Bélanger, and Rayner (2014), using prime durations of 32 and 50 ms, found facilitation when prime and target overlapped both at the orthographic and phonological level, slightly less priming when the overlap was only at the orthographic level, and hardly any priming when the overlap was phonological.

In an eye movement study of silent sentence reading, which serves as the inspiration for the current experiments, Paterson et al. (2009; see also Paterson, Alcock, & Liversedge, 2011, for related findings) tested sentences such as *There was a blur as the blue lights of the police car whizzed down the street*, which contains the prime *blur* and the target *blue*. They showed increased gaze durations on *blue* when preceded by an orthographic neighbor prime word (*blur*) compared to a control prime word (*gasp*). In contrast to single-word research which showed inhibition mainly when the *masked* prime was of higher-frequency than the target (Davis, 2003; Davis & Lupker, 2006) and when the *unmasked* prime was of lower-frequency than the target (Colombo, 1986; Lupker & Colombo, 1994; Segui & Grainger, 1990), the inhibition observed by Paterson