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Evidence for multiple routes in learning to read

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ABSTRACT

We describe a multiple-route model of reading development in which coarse-grained orthographic processing plays a key role in optimizing access to semantics via whole-word orthographic representations. This forms part of the direct orthographic route that gradually replaces phonological recoding during the initial phases of reading acquisition. The model predicts distinct developmental trajectories for pseudo-homophone and transposed-letter effects – two benchmark phenomena associated with phonological recoding and coarse-grained orthographic processing, respectively. Pseudo-homophone effects should decrease over the first years of reading acquisition, whereas transposed-letter effects should initially increase. These predictions were tested in a lexical decision task with 334 children in grades 1–5, and 29 skilled adult readers. In line with the predictions, we found that the pseudo-homophone effect diminished as reading level increased, whereas the transposed-letter effect first increased and then diminished.

1. Introduction

The average child embarking on the process of learning to read a language written with an alphabetical script comes equipped with two important pieces of prior knowledge: the letters of the alphabet (typically mastered in kindergarten), and expertise in spoken language comprehension and production entailing knowledge of the sounds of words (a phonological word-form lexicon) and their associations with meaning. It is generally agreed that children learning to read must first master the rules of sublexical spelling-to-sound translation, which is initially the most efficient means of getting from print to meaning (Share, 1995). However, it is also generally agreed that the child will eventually develop whole-word orthographic representations and their associations with semantics, which is thought to constitute another pathway for accessing meaning from print in skilled readers. These two mechanisms form the basis of a generic dual-route model of skilled reading (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Diependale, Ziegler, & Grainger, 2010; Grainger & Ferrand, 1994; Grainger & Holcomb, 2009; Grainger & Ziegler, 2011; Harm & Seidenberg, 1999, 2004; Perry, Ziegler, & Zorzi, 2007, 2010; Seidenberg & McClelland, 1989), and the basis of several influential accounts of the process of learning to read (Ehri, 1992; Frith, 1985; Seymour, 1997; Share, 1995; Ziegler & Goswami, 2005). What is less generally agreed upon, on the other hand, is the nature of the processing involved in accessing such whole-word orthographic representations, and how the beginning reader might develop such representations. Indeed, there is very little research, either empirical or theoretical, investigating the development of orthographic representations during reading acquisition (for reviews, see Castles & Nation, 2006; Metsala & Ehri, 1998, and for two recent theoretical investigations see Dufau et al., 2010; Glotin et al., 2010).

The starting point of the present research is a description of the type of representations involved in processing of the two routes of a generic dual-route model of reading. We first describe the general theoretical framework in terms of a multiple-route model of silent word reading,

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before examining the specific mechanisms that might be involved in learning the different types of representation involved in each processing route. We use the developmental framework proposed by Share (Share, 1995, 1999, 2004) in order the bridge the gap between our account of skilled reading and the processes involved in learning to read. The result is a developmental multiple-route model of how children learn to silently read words. We then derive precise experimental predictions from this framework, in terms of developmental patterns for two benchmark phenomenon associated with skilled silent word reading: transposed-letter effects and pseudo-homophone effects.

1.1. A multiple-route model of skilled reading

Fig. 1 describes a multiple-route model of printed word recognition that is basically an extension of the bi-modal interactive-activation model (BIAM) first proposed by Grainger and Ferrand (1994) and recently implemented by Diependale et al. (2010). Like the BIAM, our multiple-route model of word recognition has many similarities with dual-route models of reading aloud (Coltheart et al., 2001), and particularly the CDP + model (Perry et al., 2007, 2010). The model proposed in Fig. 1 provides a more explicit description of the processing involved in getting from print to meaning via orthographic representations alone, and draws a key distinction between location-specific and location-invariant (stimulus-centered) orthographic codes (the code that defines a set of letter identities and their positions). Another key postulate underlying this theory is that fundamentally different types of orthographic coding are involved in processing in the two routes. This forms the basis of a dual-route theory of orthographic processing that provides a further distinction between the two processing routes of the

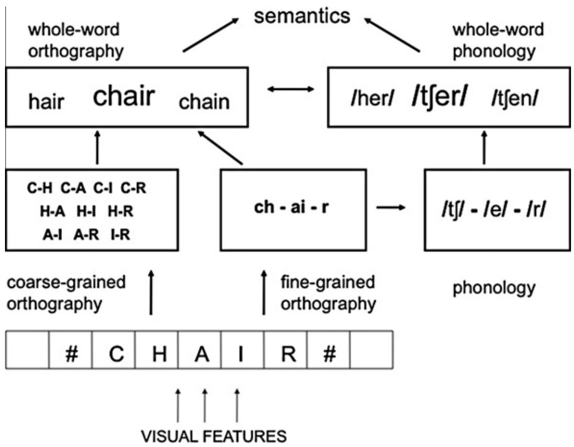

Fig. 1. A multiple-route model of word comprehension in silent reading (Grainger and Ziegler, 2011). An initial bank of location-specific letter detectors send activation forward to two types of sublexical location-invariant orthographic representation: (1) coarse-grained representations that code for the presence of informative letter combinations in the absence of precise positional information and (2) fine-grained representations that code for the presence of frequently co-occuring letter combinations (multi-letter graphemes, affixes) and provide the level of precision in position coding that is necessary to interface with sublexical phonological representations.

generic dual-route approach, going beyond the standard distinction in terms of whether or not phonology is involved (Grainger & Dufau, 2011; Grainger & Ziegler, 2011). It is the integration of the dual-route approach to orthographic processing within a generic dual-route model of word recognition that gives rise to our multiple-route model.

According to the model depicted in Fig. 1, the indirect route from print to meaning via phonology, involves fine-grained orthographic processing. That is, the system needs to know precisely the ordering of the different letter identities in the stimulus word (Goswami & Ziegler, 2006). This is particularly important for extracting contiguous letter combinations that form multi-letter grapheme representations, such as the "ch" and "ai" in the word "chair". It is also thought to be the mechanism responsible for extracting other types of frequently co-occuring letter combinations, such as affixes. Because of the need to process fine-grained orthographic structure, this route is thought to be more demanding in terms of focused spatial attention (Facoetti et al., 2006; Perry et al., 2007, 2010). Pseudo-homophone effects seen with skilled readers represent one key empirical signature of this kind of fine-grained orthographic processing. Pseudo-homophones are nonwords that can be pronounced like a real word, such as the letter string "brane" pronounced as the word "brain". These stimuli are harder to reject as nonwords in a lexical decision task (e.g., Goswami, Ziegler, Dalton, & Schneider, 2001; Ziegler, Jacobs, & Klueppel, 2001), generate more semantic categorization errors (e.g., Van Orden, 1987), and are more effective primes compared with carefully matched orthographic controls (e.g., Ferrand & Grainger, 1992, 1993, 1994; Frost, Ahissar, Gotesman, & Tayeb, 2003; Lukatela & Turvey, 1994; Perfetti & Bell, 1991; Ziegler, Ferrand, Jacobs, Rey, & Grainger, 2000; see Rastle & Brysbaert, 2006, for review). Note that these pseudo-homophone effects observed with skilled adult readers are thought to reflect fast automatic computation of sound from print upon presentation of a pronounceable string of letters (Braun, Hutzler, Ziegler, Dambacher, & Jacobs, 2009).

In the multiple-route model shown in Fig. 1, the fastest route from orthography to semantics involves coarse-grained orthographic processing. The main hypothesis here is that the skilled reader has learned to optimize the mapping of letter representations onto semantics using the best quality information in the stimulus (the most visible letters) and selecting subsets of letters that best help identify the stimulus as a unique orthographic word form. Given these constraints, it is hypothesized that such letter combinations often involve non-contiguous elements in the string (Dandurand, Grainger, & Dufau, 2010; Dandurand, Grainger, Duñabeitia, & Granier, 2011). This possibility is illustrated in Fig. 1, where it is proposed that both contiguous and non-contiguous bigrams (so-called "open-bigrams", Grainger & van Heuven, 2003) are involved in processing along the coarse-grained pathway (see Whitney, 2001, for an alternative theory of orthographic processing involving open-bigram representations). For the present purposes, there are two key properties of the coarse-grained orthographic code. The first of these key properties is the word-centered nature of the coordinate system used for letter position coding.