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Developmental dyslexia and the dual route model of reading: Simulating individual differences and subtypes ☆

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Abstract

Developmental dyslexia was investigated within a well-understood and fully specified computational model of reading aloud: the dual route cascaded model (DRC [Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J.C. (2001). DRC: A dual route cascaded model of visual word recognition and reading aloud. Psychological Review, 108, 204–256.]). Four tasks were designed to assess each representational level of the DRC: letter level, orthographic lexicon, phonological lexicon, and phoneme system. The data showed no single cause of dyslexia, but rather a complex pattern of phonological, phonemic, and letter processing deficits. Importantly, most dyslexics had deficits in more than one domain. Subtyping analyses also suggested that both the phonological and surface dyslexics almost always had more than a single underlying deficit. To simulate the reading performance for each individual with the DRC, we added

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noise to the model at a level proportional to the underlying deficit(s) of each individual. The simulations not only accounted fairly well for individual reading patterns but also captured the different dyslexia profiles discussed in the literature (i.e., surface, phonological, mixed, and mild dyslexia). Thus, taking into account the multiplicity of underlying deficits on an individual basis provides a parsimonious and accurate description of developmental dyslexia. The present work highlights the necessity and merits of investigating dyslexia at the level of each individual rather than as a unitary disorder.
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1. Introduction

Reading is a highly complex task that relies on the integration of visual, orthographic, phonological, and semantic information. The complexity of this task is clearly illustrated in recent computational models of reading (Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Harm & Seidenberg, 1999; Perry, Ziegler, & Zorzi, 2007; Plaut, McClelland, Seidenberg, & Patterson, 1996; Zorzi, Houghton, & Butterworth, 1998). For example, in the dual route model of reading aloud, the *DRC* (Coltheart et al., 2001), the reading process is fully specified as a series of interacting stages going from letter feature detection to phonological output processes. Reading aloud is achieved via two major routes: the lexical orthographic route and the nonlexical phonological route (see Fig. 1). The lexical route is necessary for the correct pronunciation of irregular words, while the nonlexical route is necessary for the pronunciation of novel words and nonwords. Accurate attentional, visual and low-level orthographic processing are necessary for normal reading via either route. The dual route model has been tested in numerous studies (Coltheart & Rastle, 1994; Rastle & Coltheart, 1999; Ziegler, Perry, & Coltheart, 2000; Ziegler, Perry, & Coltheart, 2003).

Reading impairments (dyslexia) within the dual-route framework can stem from deficits in either lexical or nonlexical processes, or a combination of the two. The idea of two representationally independent routes has been supported by the famous double dissociation between acquired *phonological* or acquired *surface* dyslexia (Coltheart, 1985). Phonological dyslexia is a condition in which after brain damage a previously skilled reader has a selective deficit in reading nonwords aloud (e.g., Funnell, 1983). Surface dyslexia is a condition in which after brain damage a previously skilled reader has a selective deficit in reading irregular words aloud (e.g., see MT, Behrmann & Bub, 1992; or KT, McCarthy & Warrington, 1986).

In contrast to acquired dyslexia, which results from a neural insult to a fully developed system, *developmental dyslexia* is a disorder that prevents the developing reading system from becoming efficient and automatized. Children with developmental dyslexia suffer from severe reading problems despite normal intelligence and teaching, and in the absence of any obvious sensory deficit (Snowling, 2000). While research on skilled reading has increasingly focused on the complex and dynamic

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