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An fMRI study of the differential effects of word presentation rates (reading acceleration) on dyslexic readers' brain activity patterns

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Abstract

Several lines of evidence have recently provided a clear indication that word reading rate can be considered as an independent variable which influences comprehension as well as accuracy in reading. Thus, not only is fluent reading a critical characteristic of skilled (automatic) reading, it has been shown that faster reading does not necessarily incur a cost in terms of accuracy. Indeed, readers of various levels of reading proficiency, as well as clearly impaired readers (dyslexics), if made to read faster than their normal (routine) reading rate, can increase their decoding accuracy and comprehension. Using block design, blood-(de)oxygenation-level-dependent (BOLD) functional magnetic resonance imaging we studied the differences in brain activation patterns induced by reading and script processing in adult dyslexics and normal reading controls as a function of two word presentation rates. Word presentation rates were set individually for each participant to correspond to his/her routine reading rate (slow) and to a correspondingly faster rate (fast). Three task conditions were tested: sentences (plausibility judgment), single words (concrete/abstract judgment), non-words (homophonic judgment). Comprehension and accuracy in the faster presentation rates were unimpaired in both groups. There were no significant differences between the activation patterns induced in both groups in 'slow' reading of sentences and single words,

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but 'fast' reading was related to higher activations in visual areas in the normal readers. However, in the slow non-words condition the dyslexics were characterized by activations in the Lt IFG (Broca's area) and operculum, while the control readers clearly activated visual processing areas (extra-striate cortex). These differences in brain activation patterns were not found in the fast non-words condition. We propose that time-constrained (accelerated) script decoding may prompt the dyslexic brain to process graphemic information in a different manner compared to the one employed in unconstrained (routine) reading, in some conditions in a manner of processing much closer to the one employed by normal reading controls.

Keywords: Reading acceleration; Acceleration phenomenon; Dyslexia; Functional brain imaging; Word presentation rates; Visual areas; Inferior frontal region

1. Introduction

Developmental dyslexia has a high incidence (5–17%) among school-age children, occurs in most known languages and results in a considerable disability in literate societies because the reading deficits persist into adulthood (Shaywitz et al., 1998). A recent report on dyslexia and literacy (British Psychological Society (BPS), 1999) proposed the following working definition of developmental dyslexia: 'Dyslexia is evident when accurate and fluent word reading and/or spelling develops very incompletely or with great difficulty'. The Health Council of the Netherlands stresses the inability to attain 'automatization', i.e. effortless, fast and accurate word identification, in dyslexics. Thus, in the view of both these experts' panels, poor readers are characterized by non-fluent, slow and inaccurate word reading (Kame'enui, Simmons, Good, & Harn, 2001; Torgesen, 2000; Wolf, 2001; Wolf, Bowers, & Biddle, 2000).

The emphasis on both accuracy and fluency reflects several changes in the current understanding of dyslexia (see Wolf (2001) for review) including a change in the common perspective that reading fluency is a result of the effectiveness of phonological processing (Lyon & Moats, 1997). Given the notion that normal reading acquisition could be conceptualized as the acquisition of non-linguistic skills (Bitan & Karni, 2004; Karni & Bertini, 1997) one may consider the possibility that gains in speed and gains accuracy in the performance of a given task may represent different aspects of knowledge (Hikosaka et al., 2002). Indeed, an improvement in both speed and accuracy with practice, rather than speed accuracy tradeoff, is a recognized characteristic of skill acquisition (procedural learning) in both motor and perceptual domains (Karni, 1996; Karni et al., 1998) although there may be phase differences in the attainment of these two parameters of performance (Korman, Raz, Flash, & Karni, 2003). The notion that skilled reading evolves in a manner similar to the acquisition of non-linguistic skills further suggests that there may be qualitative differences in the way the reading task is accomplished at different levels of accumulated experience with reading (and specific lexical items)—i.e. that different levels of brain representations may sub-serve word recognition at different stages of experience (Bitan & Karni, 2003; Clark & Wagner, 2003; Ofen-Noy, Dudai, & Karni, 2003; Papagno, Valentine, & Baddeley, 1991; Turkeltaub, Gareau, Flowers, Zeffiro, & Eden, 2003; and see, for example, in non-linguistic, motor, tasks, Korman et al., 2003; Sosnik, Hauptmann,