Do differences in brain activation challenge universal theories of dyslexia?

Johannes C. Ziegler *

Abstract

It has been commonly agreed that developmental dyslexia in different languages has a common biological origin: a dysfunction of left posterior temporal brain regions dealing with phonological processes. Siok, Perfetti, Jin, and Tan (2004, Nature, 431, 71–76) challenge this biological unity theory of dyslexia: Chinese dyslexics show no deficits in posterior temporal brain regions but a functional disruption of the left middle frontal gyrus. Here, I will argue that these data do not challenge universal cognitive theories of dyslexia according to which weaknesses in the ability to process the phonological features of language are at the origin of dyslexia.

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In primary school, one child in 10 might experience severe reading problems (developmental dyslexia) despite normal intelligence and good educational opportunities. Until recently, cognitive psychologists and neuroscientists agreed that dyslexia had the same origin in different languages: reduced activity in left temporal parietal cortex (Paulesu et al., 2001; Shaywitz et al., 1998), a brain area associated with mapping print to sound (phonology). In a recent publication, Siok, Perfetti, Jin, and Tan (2004) challenged the biological unity of dyslexia. They showed that Chinese children with dyslexia did not show the typical pattern of underactivation of the left temporal cortex. Instead, they showed reduced activity in the left middle frontal gyrus (BA 9), an area involved in visuo-spatial memory integration rather than phonological analysis (see Fig. 1). Although the authors did not claim that their findings undermined the phonological deficit theory of dyslexia, it is obvious that their data could be taken to suggest that phonological deficits are not the universal cause of dyslexia. Here, I will argue that such a conclusion would be misleading.

First, many studies have shown that phonological skills predict reading acquisition not only in English but also in Chinese (Ho & Bryant, 1997; Siok & Fletcher, 2001). As some have argued, “the most important single conclusion about reading disabilities is that they are most commonly caused by weaknesses in the ability to process the phonological features of language” (Torgesen et al., 1999). Indeed, the dyslexic children studied by Siok et al. did have a clear phonological deficit. In fact, the strongest behavioral deficit was obtained in a phonological task: homophone judgement (children had to silently read two characters and decide whether they were pronounced the same). If a phonological deficit underlies dyslexia in all languages, including Chinese, so why would brain activation of Chinese dyslexics differ from that of dyslexics in other countries? In fact, the left temporal parietal cortex performs fine-grained phonological analysis and the conversion of written symbols (letters) onto phonological units of speech (phonemes). Mapping letters onto phonemes are crucial for the acquisition of an alphabetic orthography, such as
English. Chinese readers, however, cannot use letter–phoneme correspondences for learning to read. In their logographic writing system, no part of the character corresponds to a single phoneme. Not surprisingly, the left temporal cortex in charge of phonemes is not activated in Chinese because the analysis of phonemes is largely irrelevant for reading logographic script.

Clearly, this does not mean that phonology is irrelevant for Chinese reading. Reading in all languages is about gaining access to phonological representations of words (Bosman & de Groot, 1996; Frost, 1998; Lukatela & Turvey, 1999; Perfetti, Zhang, & Berent, 1992; Rayner, Sereno, Lesch, & Pollatsek, 1995; Ziegler & Goswami, 2005; Ziegler, Tan, Perry, & Montant, 2000). However, the kinds of computations that allow access to these representations seem to differ across languages. Readers of alphabetic languages can use grapheme–phoneme correspondences. This is a highly efficient strategy: learning a small number of letters and their corresponding sounds gives children the opportunity to gain access to thousands of words that they have heard but never seen before. In contrast, readers of Chinese must learn the phonology of characters as a whole. Because decomposition at the level of grapheme–phoneme correspondences is not an option, children have to learn the approximately 3000 characters by rote. This learning problem is tremendous, and children in China might need to develop additional strategies to reduce the learning problem.

One such strategy might be reliance on writing as a means for memorizing the large number of characters. The idea is that Chinese children would create motor memories for linking spelling to phonology. This possibility has recently been supported in a study by Tan, Spinks, Eden, Perfetti, and Siok (2005) who demonstrated that writing skills were the best predictor of reading ability in Chinese children. If this interpretation is correct, the language-specific activation in the middle frontal gyrus could indeed reflect the greater reliance of the Chinese children on writing. Interestingly, the middle frontal gyrus encompasses a region often referred to as “Exner’s area,” whose damage classically entails a syndrome of “pure acquired agraphia.” Consistent with the neuropsychological data, recent brain imaging studies have found this area to be active in writing letters (Longcamp, Anton, Roth, & Velay, 2003) or logographs (Matsuo et al., 2003). Thus, if Chinese children create motor memories for linking spelling to phonology, such a process would be substantially impaired for dyslexic children who tend to have poor phonological representations.

In conclusion, it seems quite clear that children in all languages need to develop appropriate symbol–sound mapping for learning to read. In alphabetic languages, children learn to map letters onto phonemes. In logographic languages, however, children might need to learn the mapping of complex grapho-motor programs onto whole-word phonology. To perform these mappings, the brain uses different neural circuits depending on the grain size and transparency with which writing systems represent phonology (Ziegler & Goswami, 2005). At a biological level, the data by Siok et al. (2004) challenge the unity explanation of dyslexia. At a cognitive level, however, impaired phonology is still the major cause of dyslexia in all languages, including Chinese.

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References


