A neurocognitive overview of reading acquisition and dyslexia across languages

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This is a commentary on Ziegler and Goswami (2006).

In recent years, some progress has been made in the study of reading and reading disability with the use of functional neuroimaging techniques. A good deal is now known about the distributed neural circuitry for reading in skilled adult readers in multiple languages, and how reading disabled (RD) individuals differ with regard to brain organization in multiple languages (Paulesu, Demonet, Fazio, McCrory, Chanoine, Brunswick, Cappa, Cossu, Habib, Frith & Frith, 2001).

More recently neuroimaging studies have been conducted to examine the developmental trajectory toward this mature reading circuitry in typically developing children, deviations from this trajectory in reading disabled children, and the ways in which intensive training for struggling younger readers alters brain organization for reading (see Pugh, Sandak, Frost, Moore & Mencl, 2005, for a discussion). To date though, brain–behavior relational changes during the early stages of reading acquisition have been studied primarily in English-speaking learners. To separate universal from language-specific influences on neurocognitive trajectories during reading acquistion, controlled comparisons across orthographies will be essential (Ziegler & Goswami, 2006).

The world's written languages vary greatly, but there are universals. In every writing system, graphemes visually represent information about phonological or morphological features of spoken words, and discovering those correspondences between print and speech is a

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fundamental task of learning to read (Perfetti & Tan, 2005). Consequently, similar cognitive and neurobiological changes would be expected to occur across writing systems (orthographies) during development. However, differences among languages, particularly in the complexity of their orthographic-to-phonological (O → P) mappings, pose somewhat different challenges to learners (Ziegler & Goswami, 2005). Indeed, acquisition of proficient word recognition appears to be more protracted in irregular orthographies such as English than in more regular orthographies such as Finnish (Ellis, Natsume, Stavropoulou, Hoxhallari, Van Daal, Polyzoe, Tsipa & Petalas, 2004). This has implications for how we think about neurocognitive trajectories in typically developing children in different languages. Over the course of development, we hypothesize that initial between-language variation in brain organization for print will converge onto a predominantly language-invariant mature neurocognitive system (Pugh *et al.*, 2005).

Despite some developmental variability across languages and orthographies, we hypothesize that reading disability (RD) will likewise show universality. Regardless of the writing system, RD often has a genetic basis (Grigorenko, 2001) and has been associated with a common neurobiological marker – the failure to develop a functionally specialized visual word-form area (VWFA) in the left hemisphere (LH) ventral cortex (Paulesu *et al.*, 2001; Shaywitz, Shaywitz, Pugh, Mencl, Fulbright, Skudlarski, Constable, Marchione, Fletcher, Lyon & Gore, 2002). Behavioral manifestations of RD seem to differ somewhat across languages, however. Whereas slow word identification is a hallmark of RD in all orthographies, inaccuracy of mapping is seen predominantly in irregular systems like English (Wimmer & Mayringer, 2002). Thus we hypothesize that although a universal core deficit in phonological processing undermines the attainment of fluency in individuals with RD (Ziegler & Goswami, 2005), differences in orthographic regularity influence the way that RD is manifested across languages and developmental periods. We suspect that RD children in each language, as a consequence of failure to develop the LH ventral system, will maintain activation patterns seen in beginning TD readers in that language. Hence language-specific differences in early circuitry may persist in RD readers. Thus failed LH ventral development may constitute a universal (fluency limiting) marker of RD, but language-specific profiles might be informative regarding key stumbling blocks unique to a given writing system.

While we begin from the premise that typical development (TD) and reading disability (RD) will likely share common neurocognitive primitives in languages that vary in orthographic depth, we recognize that these language-invariant factors might prove difficult to uncover if we attempt to make cross-linguistic comparisons from research that is not extremely well matched on basic measures and constructs (Zeigler, Perry, Ma-Wyatt, Ladner & Schulte-Korne, 2003). To date, few cross-linguistic studies of literacy acquisition have employed well-matched longitudinal designs and samples, and as noted above, none have yet included integrated neurobiological and behavioral measures. As a result, it has not been possible to identify universal versus language-specific aspects of skill acquisition by typically developing children (TD) and those with RD at the neurocognitive level of analysis; such knowledge is crucial to a full theoretical and practical account of reading acquisition and disability.

One particularly acute issue that can be addressed with well-matched neurocognitive longitudinal studies in general, concerns gaining a better understanding of the critical neurocognitive factors associated with success or failure in attaining early 'fine-grained' phonemic awareness and the means by which this skill exerts an influence on subsequent reading development. We need to assess which aspects of language and general cognitive function (e.g. sensory processing, speech perception, quality of phonological representations, vocabulary, verbal memory, response inhibition, attentional control, verbal and nonverbal learning rates) best predict success or failure at attaining a 'fine-grained' metalinguistic skill early on, and then how these factors relate to growth in reading performance, and the neurobiological circuits for reading over time.

At Haskins Labs, we have recently begun a new collaboration with colleagues at the University of Jyvaskyla (Finland) and the Academia Sinica (Taiwan). We have developed a core set of behavioral and neurobiological experimental measures to be administered to comparable cohorts of children followed longitudinally in each country. These measures will include: (1) Behavioral tasks, conducted at key points in the course of reading development to measure the efficacy of linguistic representations, as well as to characterize general aspects of learning (e.g. rate and stability) for both verbal and nonverbal materials; (2) Neurobiological tasks to identify both the temporal (EEG) and spatial (fMRI) development of reading-relevant functional circuitry over the course of reading acquisition; and (3) Computational modeling to help to integrate our findings at each level of analysis into a unified cross-linguistic account.

A key focus in this study is on the development of reading specialization in the LH ventral cortex, and the time course of this activation with reading development. We will ask whether the developmental course is similar across languages and whether delays in ventral specialization are universally related to dysfluent reading in RD

across languages. Our central neurobiological hypothesis is that the initial neurocircuitry for reading will show a good deal of language variation for typically developing children, but that with development a common circuit (with language-specific tuning characteristics) will emerge across languages; we hypothesize that for RD children, in the absence of developing a fully-specified ventral system, some of these early language differences will be maintained and will be associated with the failure to obtain rapid and automatic word identification skills.

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