THE ROLE OF PHONOLOGICAL WORKING MEMORY IN CHINESE READING DEVELOPMENT

——*BEHAVIORAL AND FMRI EVIDENCE*

BY JING YANG

语音工作记忆对中国人阅读能力发展的影响

——来自行为和脑成像研究的证据

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CHAPTER 1 INTRODUCTION

No one was born to read. Compared with the acquisition of spoken language, reading does not occur automatically and needs much more effort. It is a complex system involving various perceptual and cognitive skills. Therefore it is not surprising to find that in English-speaking countries, about 12% – 17% of the school children (Shaywitz et al., 1998) suffer from dyslexia, which is defined as "unexpected low reading ability in people who have adequate intelligence, typical schooling, and sufficient sociocultural opportunities" (Siok, Zhendong, Jin, Perfetti, & Tan, 2008), whereas in regions using other scripts, like Chinese, 4.5%–8% of the children (Zhang et al., 1996) can be classified as dyslexics.

There is a vast amount of literature on normal reading development and reading disorders. These works, which are mostly about alphabetic writing systems, considers phonological awareness as the best predictor of reading development (for a review, see Goswami, 2000), and the core deficit underlying the reading problems of dyslexics (e.g., Bradley & Bryant, 1978). However reading is more than converting orthographic forms into phonological forms, and phonological awareness alone can not explain all the vari-

ance in reading performance of children at different reading stages (Frith et al., 1995). Other cognitive constructs have also been investigated to explore their independent contributions to reading success and to account for various deficits in dyslexia. These skills include visual and orthographic skills, naming speed, morphological awareness and working memory. So far it remains unclear whether the contributions of these factors are language-general or language-specific.

For example, in Chinese, a logographic language, the basic writing unit is a character made of strokes, which are packed into a square. The visual complexity of Chinese characters seems to suggest a more important role of visual skills in Chinese reading development, compared to alphabetic languages, such as English (e.g. Huang & Hanley, 1995; Siok & Fletcher, 2001). While some studies on Chinese support a universal role of phonological awareness (e.g. McBride-Chang et al., 2005; McBride-Chang & Chow, 2005). Others found that orthographic skill, naming speed or morphological awareness were also crucial for reading in Chinese (e.g. Ho et al., 2003; McBride-Chang & Ho, 2000; Shu et al., 2006) and could discriminate Chinese poor readers from the good readers (e.g., Shu et al., 2006).

Equally interesting is that there is increasing evidence suggesting that phonological working memory, the process of temporary storage and manipulation of phonological information, makes a unique contribution to reading development in both English (e.g., McCallum et al., 2006) and Chinese (e.g. Leong et al., 2008) languages. Phono-

logical working memory is composed of executive control, phonological store and an articulatory loop (Baddeley, 2003). Neuroimaging studies using advanced techniques, such as functional magnetic resonance imaging (fMRI) have repeatedly reported that during reading tasks dyslexics, compared to normal readers, had abnormal brain activation in regions important for phonological working memory, which include the middle frontal gyrus, inferior frontal gyrus, premotor areas, and posterior parietal regions in the left hemisphere with cerebellum as well (Baddeley, 2003; Hu et al., 2010; Paulesu et al., 1996; Vasic et al., 2008). Despite of all the findings, the nature of phonological working memory and its relation with reading is not clear. It is possible that language characteristics, tasks used and population samples recruited may account for the lack of agreement on the distinct role of phonological working memory.

To clarify the role of phonological working memory in reading, and to explore the defective neural mechanism that may underlie phonological working memory deficits in dyslexics, we conducted two studies to answer these questions. In Study 1, Chinese-English bilingual children and adults from Beijing, China completed a variety of tasks tapping their their cognitive skills including phonological awareness, visual and orthographic processing skill, naming speed, morphological awareness, phonological working memory and pinyin knowledge. Multiple regression analyses showed the independent predictive power of each cognitive construct and revealed the unique influence of phonological working memory on Chinese reading. We not only com-

pared the contributions of those factors to Chinese reading in children and adult groups, but also examined their distinct roles in different languages (Chinese, L1 vs. English, L2). To reveal the biological basis for the close relationship between phonological working memory and Chinese word reading, we conducted an fMRI experiment in Study 2. Both normal and reading-impaired children underwent fMRI scans when they completed verbal working memory tasks. By examining the temporal correlation of their blood-oxygen-level-dependent (BOLD) signal changes in selected brain regions, we identified different neural connectivity patterns between the two groups.

This book contains ten chapters. The first six chapters introduce research background for the current project. To be specific, Chapter 2 begins with a review of behavioral studies on the roles of cognitive skills in the reading development of alphabetic languages; then it summarizes main theories on word recognition and learning to read. Chapter 3 illustrates the distinct features of Chinese language and discusses previous works on Chinese reading development. Chapter 4 and 5 focus on neuroimaging findings of reading and working memory respectively. To be specific, Chapter 4 shows current knowledge of brain mechanism for normal reading in alphabetic language and Chinese; then it talks about defective neural systems underlying dyslexics' reading difficulties. Chapter 5 focuses on verbal working memory and relevant brain imaging studies, which suggest distinct neural correlates for different subcomponents of verbal working memory. Chapter 6 concentrates on evidence that phonological working memory plays an important role in word read-

ing. In this section, behavioral findings suggest phonological working memory is strongly associated with reading achievement and brain imaging studies on dyslexics' verbal working memory processing imply their aberant brain activity during the working memory task. Chapter 7 brings out the research questions of the current project and briefly introduces the research procedure and methodologies used in Study 1 and Study 2. Chapter 8 reports Study 1, a behavioral experiment, in which fourth graders and undergraduate students from Mainland China completed a series of behavioral tests, which measured their reading ability and various cognitive skills in both Chinese (their first language, L1) and English languages (their second language, L2).We used multiple regressions analyses to examine the independent contributions of those factors to their reading achievement in L1 and L2. Chapter 9 reports a neuroimaging study (Study 2) on brain mechanisms for phonological working memory processing in normal and reading-impaired children. We used 3T MRI scanner to record the functional brain activation during phonological working memory processing in good and poor Chinese young readers (ages 10–11). Our results showes group differences in brain activations at key language areas. Functional connectivity analyses based on timeseries of regions of interest (ROI) also revealed different neural activity patterns when the two groups performed the same phonological working memory tasks. Chapter 10 as the final part of this book summarizes the findings from the two studies and discusses how the current findings can shed lights on our present knowledge of reading, reading disorder, working memory and their relationships.

CHAPTER 2 READING DEVELOPMENT IN ALPHABETIC LANGUAGES

2.1 Predictors of word reading development in alphabetic languages

2.1.1 *Phonological awareness*

A large amount of literature on reading development suggests reading acquisition is strongly associated with one's phonological awareness (for a review, see Ziegler & Goswami, 2005). Phonological awareness is the ability to perceive and manipulate the sounds of spoken words (Goswami & Bryant, 1990). As one of the three subcomponent skills of phonological processing, it is said to be the most important factor influencing reading ability (Wagner & Torgesen, 1987). Tasks tapping phonological awareness often ask participants to identify and/or manipulate phonological units, such as phoneme deletion (participants are presented with a spoken word, like "cat", and are required to mentally delete a particular sound, like /k/ and say what remains, i.e. /æt/, e.g. Bruce, 1964), phoneme counting (participants are asked to speak out each sound, like /k/, /æ/, /t/ in "cat", e.g., Cheung, 1999), sound blending