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Different mechanisms in learning different second languages: Evidence from English speakers learning Chinese and Spanish

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A R T I C L E I N F O

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A B S T R A C T

Word reading has been found to be associated with different neural networks in different languages, with greater involvement of the lexical pathway for opaque languages and greater invovlement of the sub-lexical pathway for transparent langauges. However, we do not know whether this language divergence can be demonstrated in second langauge learners, how learner's metalinguistic ability would modulate the langauge divergence, or whether learning method would interact with the language divergence. In this study, we attempted to answer these questions by comparing brain activations of Chinese and Spanish word reading in native English-speaking adults who learned Chinese and Spanish over a 2 week period under three learning conditions: phonological, handwriting, and passive viewing. We found that mapping orthography to phonology in Chinese had greater activation in the left inferior frontal gyrus (IFG) and left inferior temporal gyrus (ITG) than in Spanish, suggesting greater invovlement of the lexical pathway in opaque langauges. In contrast, Spanish words evoked greater activation in the left superior temporal gyrus (STG) than English, suggesting greater invovlement of the sublexical pathway for transparant languages. Furthermore, brain-behavior correlation analyses found that higher phonological awareness and rapid naming were associated with greater activation in the bilateral IFG for Chinese and in the bilateral STG for Spanish, suggesting greater language divergence in participants with higher meta-linguistic awareness. Finally, a significant interaction between the language and learning condition was found in the left STG and middle frontal gyrus (MFG), with greater activation in handwriting learning than viewing learning in the left STG only for Spanish, and greater activation in handwriting learning than phonological learning in the left MFG only for Chinese. These findings suggest that handwriting facilitates assembled phonology in Spanish and addressed phonology in Chinese. In summary, our study suggests different mechanisms in learning different L2s, providing important insights into neural plasticity and important implications in second language education.

Introduction

Second language (L2) learning in adults is accompanied by changes in brain structure and function (Li et al., 2014; Hofstetter et al., 2016); however, little is known about how a single brain learns two different second languages simultaneously and whether there are different brain accommodations to each language. This is an important question in the literature of language learning and neural plasticity. Word reading in different languages has been found to be associated with different neural networks in native speakers (Paulesu et al., 2000; Pugh et al., 2000, Jobard et al., 2003). A body of research has examined the cross-linguistic differences in neural correlates of word reading under the framework of the dual-route model (Coltheart et al., 1993, 2001; Ziegler et al., 2000). When the language has a transparant conversion between orthogrpahy and phonology, the dural route model expects greater involvement of the sub-lexical pathway, or assembled phonology, which referes to the process of converting each grapheme to phoneme and then assembling the phonemes into a syllable. When the language has an opaque conversion between orthography and phonology, the dural route model expects greater invovlement of the lexical pathway, or addressed phonology, which referes to the process of directly retrieving stored phonological representations for the whole word. One piece of supporting evidence for the dual route model in the brain is that the left temporo-parietal conjunction area including the posterior STG and inferior parietal lobule (IPL) is more involved in the sub-lexical pathway, (Paulesu et al., 2000; Pugh et al., 2000; Jobard

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et al., 2003, Tan et al., 2003), while the left temporo-occipital area is more involved in lexical reading (Paulesu et al., 2000; Sakurai et al., 2000; Thuy et al., 2004; Cao et al., 2013b). The left IFG, however, has shown inconsistent patterns: while most studies found greater activation in this region for opaque languages (Paulesu et al., 2000; Chen et al., 2002; Bolger et al., 2005; Tan et al., 2005; Cao et al., 2013b), there is also one study that showed greater activation for transparent languages (Thuy et al., 2004). Evidence supporting the dual-route model in the brain has come from cross-linguistic comparisons using L1 reading, such as comparisons between: opaque languages and transparent languages (Paulesu, McCrory et al. 2000), Chinese and English (Bolger et al., 2005; Tan et al., 2005; Cao et al., 2013b), Chinese characters and Pinyin reading (Chen et al., 2002), and Japanese Kanji and Kana (Sakurai et al., 2000; Thuy et al., 2004). In these comparison pairs, the latter is more transparant and had greater involvement of the sub-lexical pathway while the former is more opaque and had greater invovlement of the lexical pathway. Evidence from training studies also shows a clear dissociation between the lexical and sub-lexical pathways in a comparison of addressed phonological training and assembled phonological training (Mei et al., 2014, 2015). Therefore, according to the strong evidence in the literature, one should expect greater involvement of the sub-lexical pathway including STG and IPL for word-sound conversion in transparant langauges such as Spanish and greater activation in the lexical pathway which may include the left fusiform gyrus (FG) and IFG in opaque languages such as Chinese.

Evidence supporting the dural-route model also comes from research on bilinguals, which has shown that the lexical route is more involved in opaque languages while the sub-lexical route is more invovled in transparent languages, such as in Spanish-English bilinguals (Jamal et al., 2012), Hindi-Urdu bilinguals (Kumar, 2014), and English-Chinese bilinguals (Nelson et al., 2009). A recent study suggests that one brain can adapt to different second languages by involving different brain areas during reading (Kim et al., 2016). In this specific study, Korean-Chinese-English trilinguals engaged their native Korean brain network for reading English words, but when they read Chinese words, a brain network that is more similar to native Chinese speakers was involved (Kim et al., 2016). Taken together, the bilingual/trilingual studies suggest that the brain can adapt to the properties of the language. However, these studies examined linguistic representations resulting from many years of exposure and experience, which may not have been matched for the different languages (i.e. L1, L2, L3). Therefore, in the current study, using a short-term training paradigm, we carefully matched exposure and learning methods of Chinese and Spanish written words in a group of native English speaking adults. We examined how the brain accesses word sounds from visual scripts either similarly or differently in the two newly acquired languages (Spanish and Chinese) compared to in their first language (L1) - English. We were interested in the process of conversion from orthography to phonology because this process is distinctively different in Chinese and Spanish, with English in the middle. Chinese is a logographic language in which a whole character maps to a whole syllable, with no part of the character corresponding to a single sound of the syllable. In contrast, Spanish is a transparent alphabetic language where there is a one-to-one map between grapheme and phoneme. Any word can be sounded out following the grapheme-phoneme-correspondence rule. English is considered to fall between Chinese and Spanish in terms of orthographic transparency because, even though English has the grapheme-phoneme-correspondence, the rules are less regular than Spanish. For example, one grapheme may correspond to multiple sounds and vice versa. Therefore, one may expect the brain to show different kinds of accommodation when native English speakers learn Chinese and Spanish.

While much attention has been paid to the different neurocognitive processes involved in the two pathways of orthography-phonology conversion, little has been given to how learning methods or instructions should vary to accommodate different languages. For example, learning methods that emphasize the sub-lexical procedures may be more beneficial for learning Spanish than Chinese. Phonologically-based training (i.e., language instruction that emphasizes how the sounds of a language are encoded in writing), such as phonics instruction, has proved to be effective in alphabetic languages in both typically developing children (Ziegler and Goswami, 2005) and children with reading disabilities (Carroll and Snowling, 2004; McArthur, 2012). This is most likely due to the intimate relationship between phonology and orthography in alphabetic languages. In logographic languages, such as Chinese, the importance of phonological skills in reading development has been the subject of debate. This may be due to the following: 1) Chinese orthography is very complex, and orthographic acquisition is the first step in learning to read; 2) there is no grapheme-phoneme-correspondence in Chinese, and the whole character maps to the whole syllable relatively arbitrarily; 3) there are many homophones and phonology is not reliable in accessing meaning; instead, the direct mapping between orthogrpahy and semantics is more efficient. Phonologically-based learning has never been employed in classroom instruction in Chinese, because of the lack of phonics in Chinese. Instead, repeated copying and writing has been emphasized in Chinese elementary schools.

Different from alphabetic languages, some studies have suggested that orthographic skills and handwriting skills appear to contribute more significantly to reading performance in Chinese children than phonological awareness (Rispens et al., 2008; McBride-Chang et al., 2004; McBride-Chang et al., 2005; Tan et al., 2005; Tong 2011). In adults learning Chinese as a second language, handwriting, visual grouping, and visual chunking of the constituent strokes of characters have also been found to be helpful for Chinese written word learning (Shen et al., 2012; Cao et al., 2013a; Xu, 2014). Handwriting learning is more advantageous than phonological learning in terms of establishing a high quality representation of orthography and a strong connection among orthography, phonology, and semantics (Guan et al., 2011; Cao et al., 2013a, 2013b), which is presumably due to the dedicated attention to the word's print, sound, and meaning while writing. Thus, handwriting learning has been found to be more effective than phonological learning for the acquisition of Chinese.

The benefits of handwriting, as a method for improving reading ability, have also been demonstrated in alphabetic languages, presumably because it accelerates the understanding of alphabetic principles by increasing the time and attention devoted to individual letters and their corresponding sounds during writing (Ehri et al., 2001; Rayner et al., 2001; Longcamp et al., 2003, 2005; James et al., 2005; Cao et al., 2013b). In summary, handwriting advances orthographic and phonological processes; and it has been found to be benificial for learning both Chinese and alphabetic languages. In contrast, phonological learning has mainly been effective in alphabetic languages. However, no studies have examined how the effectiveness of a particular learning method varies according to the target language, which would inform the neurocognitive models of learning and language processing.

In the current study, we trained native English speaking adults to learn Chinese and Spanish words using three different methods: handwriting learning, phonological learning, and passive viewing learning (control) using a within-subject design. We expected to find greater involvement of the lexical pathway in reading Chinese and greater involvement of the sub-lexical pathway in reading Spanish. We also expected that handwriting would facilitate word learning in Chinese because it facilitates lexical pathway processing, including the orthographic recognition and addressed phonology. We expected that handwriting would facilitate Spanish learning, because it facilitates phonological assembly in the sublexical pathway. We also expected that phonological learning would be more beneficial for learning Spanish than Chinese.