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Learning to read words in a new language shapes the neural organization of the prior languages

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ABSTRACT

Learning a new language entails interactions with one's prior language(s). Much research has shown how native language affects the cognitive and neural mechanisms of a new language, but little is known about whether and how learning a new language shapes the neural mechanisms of prior language(s). In two experiments in the current study, we used an artificial language training paradigm in combination with an fMRI to examine (1) the effects of different linguistic components (phonology and semantics) of a new language on the neural process of prior languages (i.e., native and second languages), and (2) whether such effects were modulated by the proficiency level in the new language. Results of Experiment 1 showed that when the training in a new language involved semantics (as opposed to only visual forms and phonology), neural activity during word reading in the native language (Chinese) was reduced in several reading-related regions, including the left pars opercularis, pars triangularis, bilateral inferior temporal gyrus, fusiform gyrus, and inferior occipital gyrus. Results of Experiment 2 replicated the results of Experiment 1 and further found that semantic training also affected neural activity during word reading in the subjects' second language (English). Furthermore, we found that the effects of the new language were modulated by the subjects' proficiency level in the new language. These results provide critical imaging evidence for the influence of learning to read words in a new language on word reading in native and second languages.

1. Introduction

Learning new languages, especially how to read them, is essential for social and economic success in this era of globalization. Previous studies on bilingualism have suggested that a native language can shape the cognitive and neural strategies in learning to read a second language (Akamatsu, 1999; Nakada et al., 2001; Nelson et al., 2009; Perfetti et al., 2007; Tan et al., 2003; Wang et al., 2003). For example, Tan et al. (2003) found that, compared with English monolinguals, Chinese–English bilinguals showed more activation in the left middle frontal gyrus (a region responsible for addressed phonology when reading Chinese) during word reading in English. The same cross-script effect was also confirmed by another study (Nelson et al., 2009).

Much less attention has been paid to the influence of learning to read words in a new language on word reading in a native language. Thus far, only a few studies have examined how bilinguals and monolinguals differ in the neural processes of their native language. For instance, it has been revealed that the left inferior frontal gyrus is more involved in native language processing for bilinguals than for monolinguals (Kovelman et al., 2008; Parker Jones et al., 2012; Rodriguez-Fornells et al., 2002) and for more proficient bilinguals than for less proficient bilinguals (Nosarti et al., 2010). These results suggest that long-term second language learning can affect the neural basis of native language processing. However, it is unclear whether short-term lexical learning in a new language affects the neural representations of words in prior language(s) (i.e., native language and an already acquired second language) and whether such effects occur at the orthographic, phonological, or semantic level.

Three bilingual memory models are relevant to the discussion on the effect of learning to read words in a new language on word reading in native language. The separation hypothesis

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(McCormack, 1977; Weinrich, 1953) proposes that words in the two languages are separately represented, and thus learning to read words in a new language is not expected to affect representations of the native language words. In contrast, the integration hypothesis (for reviews, please see Abutalebi and Green, 2007; Kroll and Tokowicz, 2005) postulates that the languages form a single system, although the degree of overlap between the two lexicons may vary (i.e., from partial to complete overlap) across different words. For example, concrete words may share more conceptual features than do abstract words because of the possibility of distributed lexical representations (deGroot, 1992; Finkbeiner et al., 2004). Therefore, words in the two languages would affect each other in all aspects of linguistic features including orthographic, phonologic, and semantic representations. As a compromise between the above two views, the partial integration hypothesis proposes that the languages share a common conceptual system (i.e., semantics), but that their lexical forms (i.e., orthography and phonology) are represented separately (Kroll and Stewart, 1994; Kroll and Tokowicz, 2005; Kroll et al., 2010). Thus, the partial integration hypothesis predicts that learning to read words in a new language affects neural representations of native language words only in terms of the semantic system.

In this study with two experiments, we used an artificial language training paradigm (to be described below) to examine the effect of learning to read words in a new language on the neural mechanisms of word reading in prior languages (i.e., native and second languages) and the modulatory role of proficiency in the new language. This paradigm has at least two major benefits. First, it allows for separate training of the different aspects of lexical learning (i.e., phonological vs. semantic learning) (Xue et al., 2006b) to help to disentangle their effects on the neural representations of words in prior language(s). Second, the artificial language training paradigm also allows us to examine the dynamic process, as the training progresses, of the integration between artificial language words and words in prior language(s). Previous studies have suggested that second language proficiency may be important to the neural representations of the two languages in bilinguals (Abutalebi and Green, 2007; Chee et al., 2004; Perani and Abutalebi, 2005; Perani et al., 2003, 1998; Wartenburger et al., 2003). Specifically, several previous studies have revealed that native and second languages are represented differently in the brain when the proficiency level of the second language is low, but that they share the same neural representations when the proficiency level of the second language is high (Abutalebi and Green, 2007; Perani and Abutalebi, 2005; Wartenburger et al., 2003). All these studies, however, contrasted only low with high proficiency levels without examining the dynamic changes from low to high proficiency. Our literature search did yield one behavioral study that showed a U-shaped modulatory effect of second language proficiency on native language usage. Specifically, Chen (2006) relied on a linguistic difference in the structure of causality sentences between Chinese and English. In Chinese, the typical structure is "because…so…" (called the because-initial structure), whereas in English the "because" subordinate clause can appear either before or after the main clause. To examine the modulatory effect of second language proficiency on native language usage, Chen (2006) compared three groups of Chinese–English bilinguals – native Chinese speakers who had low, medium, and high proficiency in English – in terms of their usage frequency of the because-initial structure in a Chinese causality sentence task. Results showed that the usage frequency of the because-initial structure was lower for subjects with medium proficiency in English than for either the low- or high-proficiency groups, indicating a U-shaped modulatory effect of second language proficiency. In the current training study, we also examined whether the effects of learning to read words in a new language on word reading in prior languages followed the U-shaped curve as subjects' proficiency in the new language increased.

Following our previous studies (Chen et al., 2007; Xue et al., 2006b), an artificial language was created by adopting the visual forms and sounds of 60 Korean Hangul characters, which were assigned arbitrary meanings through pictures of 60 different objects (See Fig. 1 for examples). It should be noted that these objects were semantically unrelated to the native and second language materials (i.e., Chinese and English words) used in this study to eliminate the cross-script semantic priming effect as a potential confound. To separate the effect of semantics from that of phonology of a new language on the neural representations of words in native and second languages, two training conditions were used: One involved the training of visual forms, sounds, and meanings of the words (semantic training, in short) and the other involved only the training of visual forms and sounds of the words (phonological training). The present study consisted of two experiments. In Experiment 1, training lasted

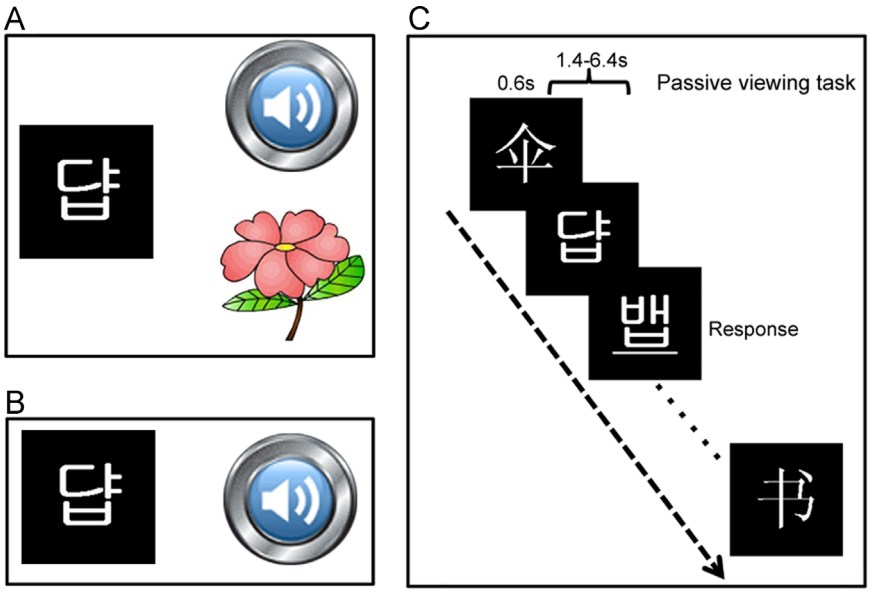

Fig. 1. Experimental design and examples of materials. Two groups of participants in Experiment 1 received 8 days of either semantic training (A), (learning the visual forms, sounds, and meanings of the words simultaneously) or phonological training (B), (learning the visual forms and sounds). Participants in Experiment 2 received semantic training for 13 days. fMRI scans were performed before training and after 8 days and 13 days of training. During the scan, participants performed a passive viewing task (C), in which subjects were asked to carefully view the stimuli and to respond if the stimulus was underlined.