Sci. Bull. (2016) 61(24):1855–1864
DOI 10.1007/s11434-016-1078-y

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Article

Life & Medical Sciences

Unsuccessful letter–sound integration in English reading by native Chinese speakers: evidence from an event related potentials study

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Received: 28 December 2015 / Revised: 18 February 2016 / Accepted: 3 March 2016 / Published online: 7 June 2016

Abstract Integrating letters and sounds are essential for successful reading in alphabetic languages. It remains unclear if native speakers of non-alphabetic languages integrate letters and sounds in reading an alphabetic language in the same way as native alphabetic readers do. Chinese is a morpho-syllabic system (each character corresponds to one syllable) and contrasts sharply with alphabetic languages such as English. Several fMRI studies have shown that native Chinese speakers apply their native language system to read English words. By using the cross-modal mismatch negativity (MMN) paradigm, we directly investigated letter–sound integration for reading in English among native Chinese speakers. To investigate the effect of native language background on letter–sound integration in second language reading, a group of native Korean English learners served as a comparison group. We compared MMN responses between an auditory only condition (only vowels presented) and two audiovisual conditions (AV0, vowel presented synchronously with the corresponding letter; AV200, the letter presented 200 ms before the corresponding vowel) for both native Chinese and native Korean speakers. Native Chinese speakers demonstrated significantly attenuated MMN amplitudes in audiovisual conditions compared with the auditory only condition, regardless of their phonological decoding speed. In contrast, native Korean speakers showed amplified amplitude MMN in AV200 compared with that in the auditory only condition. The results suggest that native language may shape the brain responses of second language learners to reading a second language in the early stages. Native non-alphabetic language speakers may be unable to use visual information to facilitate their phonological processing in the early stage while native alphabetic language speakers are capable of integrating letter sounds automatically.

Keywords Letter–sound integration · Second language reading · Native Chinese speakers · Native Korean speakers · English reading

1 Introduction

Learning to read in a second language is challenging, the more so when there are sharp contrasts between the native language and the second language. Alphabetic language systems, such as English, require associating letters (grapheme) and speech sounds (phoneme) automatically for successful reading [1]. However, Chinese, usually considered a non-alphabetic system, maps a printed character to a corresponding monosyllabic morpheme and does not apply letter–sound mapping rules in reading characters [2, 3]. This systematic difference between Chinese and English may have cognitive and neural processing consequences for native Chinese speakers learning to read English. There are 200–350 million English second language (ESL) learners who are native Chinese speakers in the mainland of China [4]. Previous studies revealed that native Chinese speakers activated the same brain areas for English word

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reading tasks as those activated for Chinese word reading tasks [5–7]; however, it remains unclear if native Chinese speakers successfully integrate letters and sounds if they activate the same brain areas for Chinese reading and English reading. In the present study, we examined whether Chinese university students, who had been learning to read in English for more than 10 years, integrate English letters and sounds for English reading in the early stage. To investigate the effect of native language background on letter–sound integration in second language reading, a group of native Korean ESL learners was served as a comparison group.

Reading in an alphabetic language abides by letter–sound conversion rules [1]. For native readers of alphabetic languages, integrating letters with sounds is essential for successful reading [8, 9]. Froyen et al. [10] developed a cross-modal mismatch negativity (MMN) paradigm as a direct method to explore the effective integration between letters and speech sounds at the early stage of reading in alphabetic languages. The MMN is elicited by any discriminable change of a repetitive sound automatically between 100 and 250 ms, in particular at the fronto-central scalp electrodes [11]. The MMN has also been used to probe neural processes of audiovisual integration phenomena [12, 13]. It has been reported that visual cues can modulate the MMN response during the processing of simple auditory tones [12, 13]. Moreover, it has been repeatedly shown to be sensitive to language-specific speech sound representations [14, 15]. In the cross-modal paradigm [10, 16–18], the MMN evoked by the same deviant vowels combined with visually presented letters corresponding to standard vowels (audiovisual condition) is to be enhanced comparing with the MMN evoked by deviant vowels (auditory only condition). Skilled native Dutch readers exhibited significantly larger MMN responses for a deviant vowel when being presented concurrently with the letter corresponding to the standard vowel than in the absence of the letter. Froyen et al. [10] interpreted the larger MMN responses in the concurrent audiovisual conditions as revealing fully automatic letter–sound integration. Moreover, the stimulus onset asynchrony (SOA) between letters and speech sounds was proven to be sensitive to the electrophysiological pattern of letter–sound integration. When letters are presented 200 ms before the sounds, the MMN enhancement diminished for adults [10], and emerged for 11-year-old children with typical reading abilities [16], suggesting that the SOA dependency of the cross-modal MMN effect is sensitive to the variation of reading abilities for native alphabetic readers. Mittag et al. [19] confirmed stronger MMN responses for the speech sounds presented with written syllables than with scrambled syllables in skilled native Finnish readers.

Although English is less transparent in letter–sound correspondence than Dutch and Finnish, behavior studies have revealed that automatic grapheme–phoneme conversion occurs during English word reading [20, 21]. Moreover, with a cross-modal MMN paradigm adapted from Froyen et al. [10], MMN responses were found much larger when the visual letter was congruent with the letter name (e.g. letter "E" and sound /i:/) than when letters and letter names were incongruent, suggesting the audiovisual integration of an English letter and its letter name occurs during relatively early pre-attentive stage of sensory processing [22]. All these cross-modal MMN investigations have opened an unprecedented window for the understanding of letter–sound conversion in the early processing of English reading of ESL learners.

As a morpho-syllabic system, learning to read Chinese characters does not entail direct grapheme–phoneme mapping rules [23]. From a neurocognitive perspective, it has been argued that native Chinese speakers were found to apply the same processing strategy for reading in their native language to reading English words. Even fluent Chinese–English bilinguals who had lived in the United States for several years still activated similar brain areas (e.g. left middle frontal gyrus) for both Chinese and English rhyming judgments of visually presented words [5]. They consistently recruited bilateral fusiform areas when passively viewing both Chinese characters and English words [6]. Similar brain activities were also observed in rhyming judgment tasks for native Chinese-speaking English learners who had no experience of living in English-speaking countries [7, 24]. The cortical regions activated for native Chinese speakers when reading in English were identified as the brain areas responsible for visual–spatial information processing and spatial working memory [25]. The inactivity of brain areas related to phonemic analysis (e.g. left superior temporal gyrus) observed in English reading by native Chinese speakers has usually been attributed to the lack of automatic grapheme–phoneme conversion in their native language reading [5–7].

However, all the studies mentioned above used word-level stimuli (real words or pseudowords) and seldom examined letter–sound integration directly. This study aimed to investigate the effect of native language on the English reading of native Chinese speakers in the early processing stage by directly manipulating the letter–sound integration. Moreover, given that the temporal resolution of fMRI is inherently limited by the slow blood flow response, it remains unclear whether letter–sound integration occurs at the early stage of processing English by native Chinese speakers. Therefore, it remains unclear whether native Chinese speakers with long-term English learning experience in school integrate letters and sounds in the early stage of reading English. To the best of our knowledge, early