Journal of Neurolinguistics 39 (2016) 57–68

Contents lists available at ScienceDirect

Journal of Neurolinguistics

journal homepage: www.elsevier.com/locate/jneuroling

Research paper

Does font type influence the N200 enhancement effect in Chinese word recognition?

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ARTICLE INFO

Article history:
Received 15 May 2015
Received in revised form 1 March 2016
Accepted 7 March 2016
Available online 13 April 2016

Keywords:
Centro-parietal N200
N200 enhancement effect
Chinese word recognition
High spatial frequency information

ABSTRACT

By manipulating font type of the prime words in an immediate repetition paradigm, we investigated whether the centro-parietal N200 enhancement effect, an electrophysiological index specific to Chinese visual word recognition as reported by Zhang et al. (2012), is influenced by high spatial frequency information of Chinese characters during orthographic processing. Participants were asked to passively view lists of two-character compound words and only indicate Korean words via button presses. A compound word was presented in a prime trial in one of three font types (i.e., Song, LiShu, or ShuTi) that differed significantly in high but not low spatial frequency information, and was immediately followed by a target trial that presented the same word in Song font. A clear N200 enhancement effect was observed for target trials in all three conditions. Manipulation of font type did not modulate the N200 effect, but did modulate earlier ERP components N1 and N270. The finding that the N200 enhancement effect is not associated with high spatial frequency information was discussed in the framework of an invariant word recognition model with a hierarchy of local combination detectors (LCDs) proposed by Dehaene, Cohen, Sigman, and Vinckier (2005).

1. Introduction

Written language has had a profound impact on human civilization as an essential medium for transferring information over long distance and storing information for long period of time. Written Chinese is distinct from other alphabetic writing systems in numerous aspects. From a philological viewpoint, Chinese and English differ significantly with respect to the relationship between characters, letters, and word-building, and between orthography, phonology, and semantics (Jia, 2002, Chap. 2). Because learning to read can alter the cortical networks for vision and language (Cao, Vu, et al., 2013; Carreiras et al., 2009; Dehaene et al., 2010), there is a possibility that the difference between Chinese characters and alphabetic writing can be associated with differences in neural structure and function. Some functional magnetic resonance imaging (fMRI) studies have shown that the right hemisphere is more important for processing Chinese characters than for alphabetic writing (April & Tse, 1979; Chen, Luo, Xu, Shang, & Liang, 2013). In addition to bilateral posterior functions in visual orthographic processing,

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http://dx.doi.org/10.1016/j.jneuroling.2016.03.001
0911-6044/

Chinese reading elicits greater frontal activation of the left middle frontal gyrus (LMFG) and less activation of the left inferior frontal gyrus (LIFG) relative to alphabetic reading (Tan, Laird, Li, & Fox, 2005).

Event-related potentials (ERPs) offer higher temporal resolution than fMRI and are useful for the study of orthographic processing. For example, N170 elicited with word stimuli is localized to posterior brain regions, such as the occipital and temporal regions, with some left lateralization (Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999; Cao, Li, Zhao, Lin, & Weng, 2011). The reduction of N400 upon repetition priming, which is sensitive to semantic and phonetic processing, is one of the most robustly observed ERP effects during visual word-processing (Luo, Hu, Weng, & Wei, 1999; Rugg, 1985). However, these electroencephalography studies have not been utilized to show differences between the processing of Chinese and alphabetic writing systems. In a previous study, Cao, Rickles, et al. (2013) showed that N170 effect elicited by Chinese characters is enhanced in English native speakers after they learnt Chinese by visual chunking training.

Zhang et al. (2012) used an immediate repetition paradigm to observe a new electrophysiological response that may be a neural indicator of the distinctive mechanisms for processing Chinese versus alphabetic writing systems. This response, referred to as the centro-parietal N200, is a widespread negative deflection with a centro-parietal focus that is elicited 200 ms post-stimulus onset, and shows a clear and large amplitude enhancement upon word repetition. This response is quite different from the N200 response elicited by English words under a masked priming paradigm, which showed a scalp distribution in the temporal and occipital regions, and a positive shift upon word repetition (Grossi & Coch, 2005). Furthermore, the N200 enhancement effect appears to be different from the no-go N2 effect in the oddball paradigm (lower stimulus probability associated with larger N2 magnitude) (Bruin & Wijers, 2002), because this N200 enhancement was present even when the probability of repetition was double that of non-repetition (Jia, Wang, Zhang, & Zhang, 2013).

Interestingly, the N200 enhancement effect is specific to written Chinese words. Xu (2008) presented a series of words to Chinese participants who spoke English as a second language and asked them to make semantic judgments of the words presented. One of the conditions involved immediate repetition of 2-character Chinese words, and indeed the N200 response was recorded at the word's first presentation and an enhanced at the word's repetition. However, in conditions involving immediate repetition of English and Spanish words, neither negative responses nor any signs of negative enhancement were recorded at repetition. Furthermore, no study conducted on English and other alphabetic writing systems in the past three decades has reported effects similar to the centro-parietal N200 nor its repetition enhancement effect (Doyle & Rugg, 1998; Doyle, Rugg, & Wells, 1996; McDonald et al., 2010; Van Strien, Verkoeijen, Van der Meer, & Franken, 2007).

Neither N200 nor its enhancement effect have been observed in studies manipulating phonological priming, or semantic priming (Du, Zhang, & Zhang, 2014; Zhang et al., 2012). These findings indicate that N200 is not influenced by phonological or semantic processes, and may therefore reflect extensive and higher-level visual analytic processing for the orthographical identification of individual Chinese words.

Zhang et al. (2013) reversed the position of two radicals in the priming character to create a pseudo-character condition and observed a reduction of the N200 enhancement effect. Du, Hu, Fang, and Zhang (2013) also observed that the N200 enhancement effect size was influenced by the position of two characters being reversed in the prime trial. These findings imply that the N200 enhancement effect is not only influenced by a holistic representation of words and characters, but also by the spatial relationship between characters or radicals. This may be due to the fact that Chinese departs from the linear layout of most alphabetic writing (Korean is an exception) and has a rectangular layout of its graphic components, comprised of radicals arranged side by side, top to bottom, or inside-outside. For instance, 口 and 木 can make up different characters (e.g. 杏, 呆, 困) when the relation of radicals changes. Therefore, the reading of Chinese characters may require configural visual processing that decodes the spatial relationships between radicals (Perfetti, Cao, & Booth, 2013).

All visual stimuli (such as writing and faces) contain a range of spatial frequency that varies in order to convey different types of information for visual processing. Low spatial frequencies represent coarse visual information and configural information in large-scale variations, whereas high spatial frequencies represent tighter gradients of luminance changes and fine visual information (Goffaux & Rossion, 2006). The potential levels of processing in Chinese include the feature and stroke level, the radical level, the character level, and the multi-character level in a multilevel interactive-activation framework (Taft & Zhu, 1997). In the feature and stroke level, the stroke contains high spatial frequency information that has fine details, which is similar to the use of high spatial frequency in English (e.g. dear vs. deer in English; 凤 vs. 凤 in Chinese). However, above the feature and stroke level, the configural relationships between strokes and radicals contain low spatial frequency information (Chua, 1999; Perfetti et al., 2013). Chinese more than linear alphabetic writing uses configural (low spatial frequencies) information to differentiate written morphemes. Therefore, visual processes tuned to low spatial frequencies could be especially important for reading Chinese (Perfetti et al., 2013).

N200 and its enhancement may therefore have some relation to the processing of low spatial frequency information. However, previous studies have not successfully identified the relationship between N200 enhancement and high frequency information. For example, the font size of priming word was manipulated to explore the influence of physical features on the N200 enhancement effect, and it was found that the different sizes of characters elicit almost identical enhancement effects (Zhang et al., 2013). In addition, Zhang et al. (2012) presented Chinese participants with Chinese and Korean words in an immediate repetition paradigm and found that Chinese words elicited a significant N200 enhancement effect while there was no difference between the control and repeat conditions for Korean words. These results suggest that low-level and non-linguistic physical features do not contribute to the N200 enhancement effect. However, these studies were unable to distinguish the influence of high spatial frequency information processing on the N200 enhancement effect because they did