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Music reading expertise modulates hemispheric lateralization in English word processing but not in Chinese character processing



Sara Tze Kwan Li, Janet Hui-wen Hsiao*

Department of Psychology, University of Hong Kong, Hong Kong Special Administrative Region

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ABSTRACT

Music notation and English word reading both involve mapping horizontally arranged visual components to components in sound, in contrast to reading in logographic languages such as Chinese. Accordingly, music-reading expertise may influence English word processing more than Chinese character processing. Here we showed that musicians named English words significantly faster than non-musicians when words were presented in the left visual field/right hemisphere (RH) or the center position, suggesting an advantage of RH processing due to music reading experience. This effect was not observed in Chinese character naming. A follow-up ERP study showed that in a sequential matching task, musicians had reduced RH N170 responses to English non-words under the processing of musical segments as compared with non-musicians, suggesting a shared visual processing mechanism in the RH between music notation and English non-word reading. This shared mechanism may be related to the letter-by-letter, serial visual processing that characterizes RH English word recognition (e.g., Lavidor & Ellis, 2001), which may consequently facilitate English word processing in the RH in musicians. Thus, music reading experience may have differential influences on the processing of different languages, depending on their similarities in the cognitive processes involved.

1. Introduction

Recent research has shown that different perceptual expertise domains may influence each other. For example, Gauthier, Curran, Curby, and Collins (2003) showed that car perception interfered with concurrent face perception in car experts (presumably also face experts), but not in car novices, suggesting that car and face expertise can influence each other (see also Gauthier, Skudlarski, Gore, & Anderson, 2000). A similar effect was observed in a visual search task with face targets, in which reaction time was increased by the appearance of car distracters in car experts but not in car novices (McGugin, McKeeff, Tong, & Gauthier, 2011). In an ERP study, Rossion, Kung, and Tarr (2004) showed that expertise with a non-face object type, greebles, led to substantial decrease in N170 amplitude in response to faces with concurrent greeble presentation, suggesting different expertise domains can influence each other in early perceptual processing.

Similarly, expertise in music reading may influence cognitive processes involved in other perceptual expertise domains. Indeed, recent research has suggested that music training may result in changes in brain development and enhancement in some cognitive skills. For example, music training at an early age has been reported to result in a thicker corpus callosum, suggesting enhanced hemispheric

communication (e.g., Münte, Altenmuller, & Jancke, 2002; Schlaug, Jäncke, Huang, Stagier, & Steinmetz, 1995; see also Patston, Kirk, Rolfe, Corballis, & Tippett, 2007). Consistent with this finding, music training is shown to enhance visuospatial abilities (e.g., Costa-Giomi, 1999; Graziano, Peterson, & Shaw, 1999; Hassler, Birbaumer, & Feil, 1987; Hetland, 2000; Rauscher, Shaw, & Key, 1993). Musicians are also found to have a more bilaterally represented visuospatial attention (e.g., Patston, Corballis, Hogg, Tippett, 2006; Patston, Hogg, & Tippett, 2007), in contrast to non-musicians who typically have an asymmetry to the left side of the space due to stronger activation of the right hemisphere (RH) than the left hemisphere (LH) in response to visuospatial processing (Vingiano, 1991). These changes in visuospatial abilities are possibly due to developed music notation reading skills (Brochard, Dufour, & Despres, 2004).

Neuropsychological data have suggested that the LH plays an important role in music reading. Studies of brain injured musicians who lost the ability to read music notation consistently showed posterior LH damage, in particular in the left occipitotemporal (e.g., Judd, Gardner, & Geschwind, 1983) and posterior temporoparietal regions (e.g., Stanzione, Grossi, & Roberto, 1990; see Hébert & Cuddy, 2006, for a review). Consistent with this finding, Segalowitz, Bebout, and Lederman (1979) reported a right visual field (RVF)/LH advantage in a

^{*} Corresponding author at: Department of Psychology, University of Hong Kong, Pokfulam Road, Hong Kong Special Administrative Region. E-mail address: jhsiao@hku.hk (J.H.-w. Hsiao).

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tachistoscopic music chord identification task in musicians, suggesting the involvement of LH processing in reading music notation (see also Salis, 1980).

LH processing has been shown to be analytic (Bradshaw & Nettleton, 1981), which facilitates decoding of music notations into pitch classes and rhythms. This decoding process is similar to the grapheme-phoneme correspondence in alphabetic languages (e.g., English). Indeed, recent research on visual word recognition has shown LH lateralization in reading words in alphabetic languages such as English. A classical RVF/LH advantage has been consistently reported in various tachistoscopic English word recognition tasks, such as word naming (e.g., Bradshaw & Gates, 1978; Brysbaert & d'Ydewalle, 1990) and lexical decision tasks (e.g., Barry, 1981; Measso & Zaidel, 1990). fMRI studies have shown a region inside the left fusiform area (Visual Word Form Area) responding selectively to words and pseudowords following the orthographic regularities in English (e.g., McCandliss, Cohen, & Dehaene, 2003). ERP studies also show that words elicit a larger N170 in the LH than the RH (e.g., Rossion, Joyce, Cottrell, & Tarr, 2003). This RVF/LH advantage in English word processing has been argued to be due to left-lateralized phonological processing for grapheme-phoneme conversion (Maurer & McCandliss, 2008; Rumsey et al., 1997). Similarly, the RVF/LH advantage in identifying music chords (Segalowitz et al., 1979) may be related to the requirement of mapping individual notes to different pitches/fingerings. In addition, for both English words and music notations, components are horizontally arranged, and the reading direction is from left to right. This left-to-right reading direction may contribute to better word/music notation reading performance in the RVF/LH due to perceptual learning, since words/music notations are recognized in the RVF more often than the LVF during reading (Brysbaert & Nazir, 2005; Wong & Hsiao, 2012).

While the LH is shown to play an important role in both English word and music notation reading, the RH is also involved, particularly in visual form processing of words and notes. For example, in a lexical decision priming task, English word processing in the LVF/RH was shown to benefit from orthographically similar primes, whereas that in the RVF/LH benefited from phonologically similar primes. This result suggested that the RH and the LH had differential advantages in orthographic and phonological processing of English words (Lavidor & Ellis, 2003). Consistent with this finding, English word processing in the RH has been reported to be more sensitive to variations in visual word forms. For example, the word length effect in English lexical decisions (i.e., faster and more accurate responses to shorter words) was only observed when words were presented in the LVF/RH but not the RVF/ LH, suggesting that RH word processing involves more letter-by-letter recognition/serial visual processing than that in the LH (Lavidor & Ellis, 2001). Similarly, in music note processing, a right lateralized or bilateral visual processing mechanism has been observed. For example, fMRI studies have shown that the right occipitotemporal region was associated with music sight-reading (Schön, Anton, Roth, & Besson, 2002). Bilateral activations in the fusiform and inferior occipital gyri in musicians were also reported in a note selection task (Proverbio, Manfredi, Zani, & Adorni, 2013).

Although previous research has suggested similarities between English word and music notation reading processes, it remains unclear how they influence each other. While both skills seem to involve both left and right hemisphere processing, they differ significantly in their involvement in lexical processing. More specifically, English words follow morphological and orthographic rules with clearly defined segment boundaries and lexical representations, whereas musical segments do not follow as strict sequencing rules as words and are not associated with specific phonological or semantic representations (Chan & Hsiao, 2016). Thus, the similarities in their processing may be mainly in the serial visual processing of horizontally arranged components that characterizes RH English word processing (e.g., Lavidor & Ellis, 2001). Also, since previous research has suggested that LH English word processing is more relevant to phonological processing of English words

whereas RH English word processing is more sensitive to variations in visual word forms, the modulation of music reading experience on English word processing is more likely to be due to a shared visual processing mechanism in the RH.

In contrast to English word processing, the recognition of Chinese characters, a logographic writing system, has been shown to have a left visual field (LVF)/RH advantage in tachistoscopic character identification/naming (Cheng & Yang, 1989; Tzeng, Hung, Cotton, & Wang, 1979) and lexical decision tasks (Leong, Wong, Wong, & Hiscock, 1985). More recent research suggests an RH/LVF advantage in Chinese orthographic processing and an LH/RVF advantage in phonological processing (e.g. Leong et al., 1985; Yang & Cheng, 1999). In addition, the LH lateralization in phonological processing in Chinese character recognition depends on both character type and structure (Hsiao & Cheng, 2013; Hsiao & Liu, 2010; Weekes & Zhang, 1999). ERP and fMRI studies have also shown a more bilateral or RH-lateralized activation in the visual system with Chinese characters as compared with English words (e.g., Hsiao, Shillcock, & Lee, 2007; Tan, Laird, Li, & Fox, 2005; Tan et al., 2000).

The right-lateralized Chinese orthographic processing has been argued to be due to its logographic nature (e.g., Hsiao & Lam, 2013; Lam & Hsiao, 2014). More specifically, in Chinese orthography, each character is regarded as a morpheme and corresponds to a syllable in the pronunciation, and components of a character do not correspond to phonemes in the pronunciation. In other words, there is no graphemephoneme correspondence in Chinese, and consequently Chinese character recognition may involve less left-lateralized phonological processing for grapheme-phoneme conversion as compared with word recognition in alphabetic languages such as English (e.g., Maurer & McCandliss, 2008). In addition, different from English words and music notations, Chinese characters can be read in all directions (left to right, right to left, or vertically). The effect of perceptual learning due to reading direction thus may have less influence on lateralization effects in Chinese character recognition than in English word recognition. As for RH visual processing requirements, components of a Chinese character can appear in different configurations, including left-right, top-bottom, and enclosed structures. Also, left-right structured Chinese characters typically consist of only two to three components, in contrast to English words or musical segments. Thus, the recognition of Chinese characters does not rely on serial visual processing of horizontally arranged components as much as that of English words or music notations. Due to these differences, the modulation effect of music reading experience on Chinese character processing may be weaker than that on English word processing.

Accordingly, here we examine how music reading experience influences English word and Chinese character processing. We hypothesize that there will be a stronger modulation effect of music reading experience on English word processing than Chinese character processing due to the similarities between the processes involved in reading English words and music notations, and this modulation effect is likely to be related to RH visual processing mechanisms. To test these hypotheses, here we recruit musicians and non-musicians who are also Chinese-English bilinguals and investigate whether they differ in hemispheric lateralization effects in English word and Chinese character processing. In Experiment 1, we conduct English word and Chinese character naming tasks through the divided visual field paradigm (Bourne, 2006). We predict that musicians may perform better than non-musicians when English words are presented in the LVF/RH due to the similarities in visual processing between English word and music notation reading. In contrast, musicians and non-musicians may not differ in the lateralization effect in the Chinese character naming task. In Experiment 2, to examine the neural correlates of possible modulation effects of music notation reading experience on visual processing of English words, we conduct an ERP study in which participants perform a sequential matching task with English word stimuli. Following Rossion et al. (2004), we examine how N170 responses to

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