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COGNITIVE SCIENCE & NEUROSCIENCE | RESEARCH ARTICLE

Hemispheric processing of Chinese hànzì and English words: A lateralized lexical decision study

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Abstract: We presented orthographic English words or Chinese logographic hànzì primes to either the left or right visual fields followed by a semantically related target to the opposite visual field. Chinese hànzì primed English words in both hemispheres but English required right-hemisphere involvement to prime hànzì symbols. This study suggests that Chinese hànzì and English word translation recruits both hemispheres. Our results are consistent with the conclusion that the two cortical hemispheres maintain parallel, but different, representations of hànzì, just as has been shown with English words.

Subjects: Behavioral Sciences; Cognitive Neuroscience; Psychological Science

Keywords: semantic priming; laterality; hemisphere; bilingual translation; Chinese hànzì

1. Introduction

Lateralized lexical decision tasks (Collins & Loftus, 1975; Quillian, 1968) provide a means of contrasting semantic processing in the two hemispheres and understanding mental representation (Meyer & Schvaneveldt, 1971; Schvaneveldt, Meyer, & Becker, 1976). The semantic priming literature strongly supports the conclusion that both hemispheres have similar lexicons and that activation of meaning is initially similar in both hemispheres; but over time only dominant meanings are available to the left hemisphere while remote meanings remain available to the right hemisphere (Burgess & Simpson, 1988; Chiarello, 1985, 1998; Coslett & Saffran, 1998; Whitman, Holcomb, & Zanes, 2010).

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PUBLIC INTEREST STATEMENT

This is a study exploring how the two hemispheres of the brain translate meaning from one language to another. In this study we studied translation of a phonemic language, English to a more pictorial, logographic, language, Chinese hànzì when English or hànzì symbols were presented to one of the hemispheres. We showed that the two cortical hemispheres maintain parallel, but different, representations of these lexical forms of the two languages and that efficient translation requires cross-hemisphere integration of both representations.

Evidence is available to support arguments both that two languages may share a common cortical representation (Kolers, 1963) and that they are independently represented (Glanzer & Duarte, 1971). Deficit patterns in bilingual aphasics and neuroimaging results support the position that distinct cortical networks exist in the left- and right hemispheres for first and second language processing (Gandour et al., 2007; Illes et al., 1999; Kim, Relkin, Lee, & Hirsch, 1997). Some neuroimaging studies report a more widely distributed left-hemisphere network for the second language (Golestani et al., 2006) and greater bilateral recruitment during second language processing (Cheung, Chan, Chan, & Lam, 2006; Liu, Hu, Guo, & Peng, 2010). In contrast, several imaging experiments report evidence in support of a common cortical network for both languages (Chee, Tan, & Thiel, 1999; Klein, Milner, Zatorre, Zhao, & Nikelski, 1999).

In addition, the right hemisphere is engaged to a greater extent than the left hemisphere when a task elicits or requires visual-spatial analysis, as would be the case in processing logographic stimuli (Gazzaniga, Bogen, & Sperry, 1965; Kimura, 1969). Grose-Fifer & Deacon, using a lexical decision task, found a right-hemisphere advantage for prime-target pairs with a high degree of visual feature overlap (e.g. mosquito–flea vs. sofa–vase) {Grose-Fifer, #12608). And, a meta-analysis of 286 studies examining gender differences on visual-spatial tasks reported a small but highly reliable difference favoring men on visual-spatial tasks (Voyer, Voyer, & Bryden, 1995)

Research suggests greater right-hemisphere involvement in processing the meaning of logographic symbols (Mei et al., 2015; Wang, 1973; Yang & Cheng, 1999). Japanese stroke victims show different degrees of deficits in kana (phonemic-based Japanese script) compared to kanji (Iwata, 1984; Sasanuma & Monoi, 1975). Studies using lexical decision tasks, the Stroop task, and visual half-field presentations using logographic and orthographic symbols, report greater left-hemisphere superiority for orthographic stimuli and a right-hemisphere superiority for logographic stimuli (Biederman & Tsao, 1979; Fang, Tzeng, & Alva, 1981; Hatta, 1981; Hirata & Osaka, 1967; Rastatter & Scukanec, 1990; Tsao, Wu, & Feustel, 1981). This asymmetry is confirmed by neuroimaging studies and studies using subjects with lateralized brain damage (Cheung et al., 2006) and subjects processing numeric symbols (Holloway, Battista, Vogel, & Ansari, 2013) and words (Tan et al., 2000; Yiyuan et al., 2002).

Languages employing logographic and orthographic symbols, such as Mandarin Chinese, provide a unique opportunity to assess the contributions of the cortical hemispheres to language processing. Utilizing a procedure similar to Hutchinson, Whitman, Abeare, and Raiter (2003) we presented semantically related targets to either the primed visual field or to the opposite visual field. We predicted that strong prime-target associates would show greater priming than weaker associates and that logographic hànzì would prime orthographic words in both hemispheres but that orthographic words would show weaker priming of logographic targets presented to the left hemisphere, due to the right hemisphere's advantage both for visual-spatial content and broader semantic priming.

2. Method

2.1. Participants

Thirty, right-handed (Oldfield, 1971), Chinese students between the ages of 18 and 35, fluent in both Mandarin Chinese and English (with an average of 10.6 years of English), were tested in single sessions lasting approximately one hour. Informed written consent was obtained from each participant in compliance with a protocol approved by Human Investigations Committee of Wayne State University.

2.2. Stimuli and procedure

Targets were either high or low frequency associates of their English equivalent prime words (Nelson, McEvoy, & Schreiber, 1994) previously used by Hutchinson et al. (2003). The best equivalent Chinese logograph for the English equivalent was chosen (e.g. bed and Chinese logograph for "sleep"). English or Chinese primes were followed by either an English word, or a pronounceable nonsense word, or a Chinese logograph, or a non-meaningful Chinese logograph. Nonsense words were created by altering a single phoneme of an English word (e.g. "MEAM") and Chinese non-meaningful logographic stimuli were constructed by replacing ideographic characters (see Figure 1). Target stimuli consisted of 50% meaningful and 50% nonsense words or meaningless logographic symbols to avoid the development of a biased response pattern.

Stimuli were presented on a 166 MHz Pentium 2 personal computer using SuperLab Pro to generate the experiment and record both reaction time and subject accuracy. A fixation point (+) was presented at the center of the screen and participants were instructed to focus their gaze on that spot at all times All stimuli were presented with the inside edge of primes and targets 2.5 degrees to the left or right of center. Participants were positioned 40 cm from the computer screen using a chin rest.

The experiment consisted of 552 trials divided into two blocks; blocks of trials consisted of the prime word or a logogram appearing on either the right or left side of the screen for 35 ms followed by a 15-ms mask of white noise (total Stimulus Onset Asynchrony = 50 ms). This SOA was chosen for this initial study because it reliably resulted in semantic priming in previous studies using English primes and targets. Targets were presented on either the right or left side for 185 ms and the participant indicated whether it was a word by pressing the appropriate key on the keyboard (using the right hand). In addition, half the trials presented the prime and target to the same visual field (ipsilateral priming) and half the trials presented the prime and target to different visual fields (contralateral priming). This SOA, and method, has shown to effectively prime related words in prior studies.

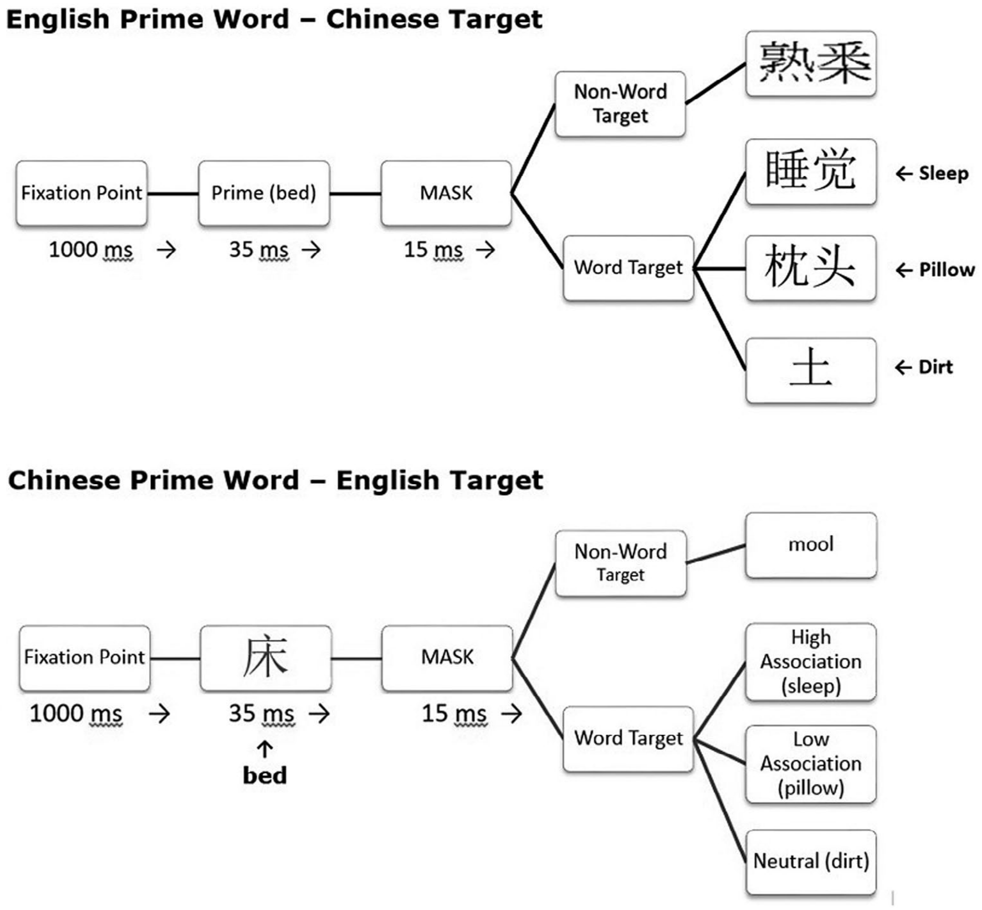
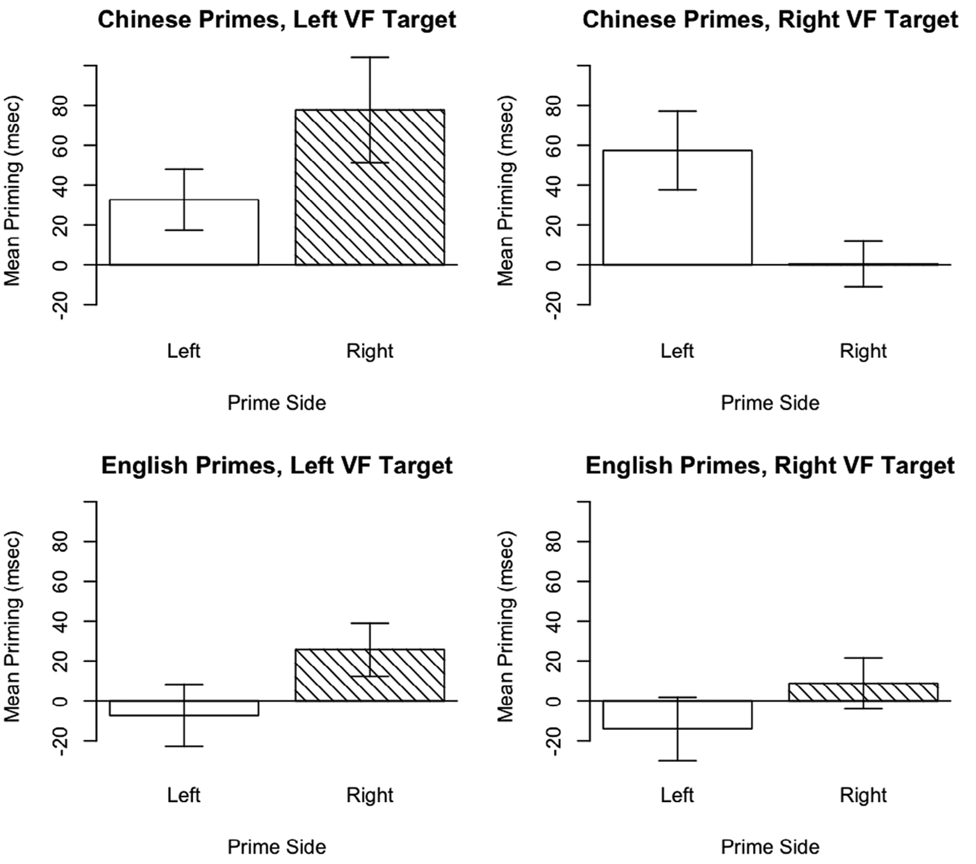


Figure 1. Chinese and English primes were presented in two blocks of trials counterbalanced across subjects.

Notes: Trials consisted of a focusing mark (*) for 1,000 ms, followed by the prime, projected to either the left or right visual field for 35 ms, followed by a 15-ms pattern mask (total SOA = 50 ms). In one-half of the trials, the prime and target were projected to the same visual field; in the other half, they were projected to opposite visual fields.

Figure 2. Mean priming for Chinese (Top) and English (Bottom) primes, contrasting the prime and target visual fields.

Notes: Mean reaction time was computed on each subject based on correct lexical decisions. The priming effect was calculated as the difference in reaction times between the related and the unrelated trials. For Chinese stimuli, priming the left visual field (right hemisphere) resulting in semantic priming in both hemispheres. Chinese stimuli presented to the right visual field (left hemisphere) primed only right hemisphere.



3. Results

Priming was calculated by subtracting the mean reaction time of the related associates from the mean reaction time of the neutral associates for each condition. A 2 (Association strength) × 2 (Prime side) × 2 (Target side) by 2 (Chinese vs. English) ANOVA was conducted on reaction time data. Chinese hànzì primed more strongly than English primes, F (1, 28) = 17.9; $p < .001$. High associates primed more than low associates, F (1, 28) = 13.95; $p < .001$. And, there is a suggestion of greater priming for left visual field—right hemisphere (LVF/RH) targets than for right visual field—left hemisphere (RVF/LH) targets, F (1,28) = 5.1; $p < .03$.

As seen in Figure 2, there is also a trend of greater cross-hemisphere priming than same-side priming; a RVF/LH prime was more effective for a LVF/RH target and a LVF/RH prime was more effective for a RVF/LH target than the equivalent same-sided conditions, F (1,28) = 6.14; $p < .02$. Chinese hànzì, in either the LVF or RVF, showed strong priming; however, English words only primed targets in the RVF/LH, F (1,28) = 4.29; $p < .05$.

4. Discussion

The strong effect of association strength, a standard finding in the semantic priming literature, confirms the effectiveness of the priming procedure. The primary predictions regarding translation priming were also confirmed: Hànzì effectively primed English words in either visual field; English primes did not prime hànzì targets presented to the left hemisphere, though they weakly primed hànzì targets presented to the right hemisphere. This demonstrates a hemispheric asymmetry of lateralized semantic priming of Chinese logographic symbols and English words.

This pilot study is limited by a number of factors. The subjects were all right-handed males. The greater right-hemisphere engagement by hànzì may be related to their visual-spatial nature and/or to a different organization of the lexicon for hànzì in the left and right cortical hemispheres. Also, reliable measures of association strength for English words is available but the degree to which its orthographic or logographic match is its approximate equivalent is unknown. Hànzì are often constructed by combining symbols with multiple meanings. For example, "paperback" is constructed of the symbols for paper, book, and read. Each of these might prime different conceptual networks of associations.

Nevertheless, this also provides another explanation for these findings. Hànzì might prime the right hemisphere's "looser," or more polysemous, semantic network. Priming studies using ambiguous target words report greater facilitation of the right hemisphere when the prime word and target words were mixed (ambiguous) but a greater left-hemisphere facilitation when the primes converged on a single dominant or subordinate meaning (Atchley & Burgess, 1998; Atchley, Burgess, & Keeney, 1999; Atchley, Keeney, & Burgess, 1996; Faust, Bar-lev, & Chiarello, 2003). Evoked potential research also suggests that the left hemisphere is biased toward a single representation of Chinese polysemic words; in contrast to the right hemisphere (Huang, Lee, Huang, & Chou, 2011). Using MEG, Hsu, Lee, & Marantz (Hsu, Lee, & Marantz, 2011) found that the right and left hemispheres differed in their involvement in analyzing different types of Chinese forms.

Klepousniotou (2002) found faster reaction times and greater priming effects were observed for metonymous words than for homonymous words indicating different processes in the recognition of ambiguous words depending on the type of ambiguity. And, research suggesting a critical right-hemisphere role in inference processing in narrative speech, as well as the literature on lateralized semantic priming using a range of stimulus-onset-asynchronies (Abeare, Hill, Zuverza-Chavarria, Geenen, & Whitman, 2005), also suggests that the two hemispherically separated representations of the lexicon may operate different activation onset and duration of semantic priming.

This study demonstrates that hemispheric asymmetry of Chinese hànzì and English word translation recruits both hemispheres. Our results are consistent with studies, using English primes and targets, that the two cortical hemispheres maintain parallel, but different, representations of these lexical forms and that efficient translation requires cross-hemisphere integration of both representations (Beeman, 1993; Beeman, Friedman, Grafman, & Perez, 1994; Chiarello, Burgess, Richards, & Pollock, 1990; Chiarello, Liu, Shears, Quan, & Kacinik, 2003).

Future research needs to address a number of related factors. Behavioral and neuroimaging evidence suggests that females have greater bilateral cerebral organization, particularly in language processing regions, whereas males show greater left-hemisphere dominance (Kansaku, Yamaura, & Kitazawa, 2000; McGlone, 1980). Age of acquisition of the second language (Badzakova-Trajkov, Kirk, & Waldie, 2008; Kim et al., 1997; Park, Badzakova-Trajkov, & Waldie, 2012; Weber-Fox & Neville, 1996) and level of proficiency (Meschyan & Hernandez, 2006; Perani et al., 1998) also contributes to different cortical activation patterns for the first and second languages. In this study, in addition to the other factors discussed above, we used a single stimulus-onset-asynchrony; and employing multiple SOAs may provide a more detailed time line for hemispheric involvement. Future research should focus on gender, handedness, a more explicit examination of the multiple meanings of logographic symbols, the degree to which any words elicit visual images, and the nature of the onset and duration of semantic priming for logographic and orthographic stimuli.

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Competing interests
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