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Limitations of translation activation in masked priming: Behavioural evidence from Chinese-English bilinguals and computational modelling

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ABSTRACT

Electrophysiological and behavioural evidence suggests that Chinese translations of English words are automatically activated when Chinese-English bilinguals read English words (e.g., Thierry & Wu, 2007; Wu & Thierry, 2010; Zhang, van Heuven, & Conklin, 2011). The present study investigated the impact of translation activation in three behavioural experiments with in total 118 Chinese-English bilinguals. First, we investigated whether Chinese phonology was the source of the effects of Chinese character repetition in the Chinese translations of English masked primes and targets (hidden repetition priming) observed in Zhang et al.'s (2011), and whether these hidden repetition priming effects were affected by Chinese morpheme complexity and prime duration. However, we failed to find any evidence of hidden repetition priming. An exact replication of Zhang et al. (2011) was conducted next, which again provided no evidence for hidden repetition priming. However, cross-language priming data collected with the same group of participants did reveal masked translation priming and crucially Chinese character repetition priming with masked Chinese primes and English targets (partially hidden repetition priming), indicating that the activation of Chinese translations in the masked priming paradigm is limited to English target words. Computational modeling work provided further support that translation form activation is limited to target words in the masked priming paradigm.

Introduction

Bilinguals have the unique ability to translate words between their languages. Although translation seems a deliberate and conscious process, recent research has shown that first language (L1) translation equivalents are automatically activated during second language (L2) word reading (e.g., Meade, Midgley, Sevcikova Sehyr, Holcomb, & Emmorey, 2017; Morford, Wilkinson, Villwock, Piñar, & Kroll, 2011; Thierry & Wu, 2007; Wu, Cristino, Leek, & Thierry, 2013; Wu & Thierry, 2010, 2012a, 2012b; Zhang, van Heuven, & Conklin, 2011). In an event-related potentials (ERP) study, Thierry and Wu (2007) presented proficient Chinese-English bilinguals with pairs of English words and asked them to judge whether these word pairs were related in meaning or not. Unknown to the participants, the Chinese translation of the critical English word pairs had a repeated character, e.g., train [火车] – ham [火腿]. The logic of this elegant design is that, when bilinguals performed differently to the English word pairs with a hidden repeated character compared to control pairs without hidden repeated characters, the Chinese translations of the English words must have been activated. A reduction of the N400 amplitude was found for English word pairs with repeated characters in their Chinese translations. Therefore, the ERP data provided evidence for a hidden repetition priming effect (hereafter the term hidden repetition is used to refer to the repetition in the Chinese translations of the English word pairs).

In their follow-up study, Wu and Thierry (2010) further investigated whether Chinese phonology and/or orthography was activated. Using the same paradigm, Chinese translations of critical English pairs either shared a homophone or a homograph. For example, *experience* [经验, /**Jing1**Yan4/] – *surprise* [惊讶, /**Jing1**Ya4/] created a pure hidden phonological repetition, whereas the hidden repetition of *accountant* [会计, /Kuai4Ji4/] – *conference* [会议, /Hui4Yi4/] was only in the orthographic forms. The ERP data showed a reduced N400 for the hidden phonological repetition but not for the hidden orthographic repetition, suggesting that Chinese-English bilinguals activate the phonology rather than the orthography of the Chinese translations. This Chinese phonological activation during English word reading was successfully replicated in another electrophysiological study by Wu and Thierry (2012a) which manipulated the emotional valence of prime words. Furthermore, additional evidence for Chinese phonological activation during English word reading came from Wu and Thierry's (2012b)

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study that involved a non-linguistic task. In this study, Chinese-English bilinguals were presented with shapes (e.g., square or circle) mixed with English words. The participants' task was to differentiate circles and squares by pressing buttons and to ignore English words. Importantly, critical English words had phonological overlap with the words *circle* or *square* when translated into Chinese (e.g., the first character of the Chinese translation of *reason* is a homophone of the Chinese translation of *circle*). When comparing these critical words with hidden phonological overlap to the control words, an increased N200 amplitude was observed. Because a more negative-going N200 was assumed to index inhibition, these findings revealed that the activation of Chinese phonology of translations from critical English words caused interference in bilinguals. Adapting this novel paradigm in an eye-tracking study, Wu et al. (2013) also found the evidence of phonological activation of Chinese translations during English words reading in Chinese-English bilinguals. Taken together, these studies provided a strong case for the co-activation of translation equivalents.

It is important to point out that the electrophysiological and eye-tracking studies by Wu and Thierry always involved processing of *visible* English words. Furthermore, the evidence for the activation of translations was found in ERP and eye-tracking data but not always in behavioural responses. To investigate whether Chinese translations are activated when English words are *subliminally* presented, Zhang et al. (2011) combined the masked priming technique with the hidden repetition paradigm developed by Thierry and Wu (Thierry & Wu, 2007; Wu & Thierry, 2010). In Zhang et al. (2011) behavioural masked priming study, Chinese-English bilinguals were asked to perform a lexical decision task with English target words, which were preceded by English primes presented for 59 ms. Faster responses were found to targets when the Chinese translation of the prime was the first character in the Chinese translation of the target (e.g., *east* [东] – *thing* [东西]), but not when the Chinese translation of the prime was the second character in the Chinese translation of the target (e.g., *west* [西] – *thing* [东西]). These results provided behavioural evidence for the activation of Chinese translations of the English prime and target. Although the findings of Zhang et al. (2011) support the idea of fast and automatic translation of primes and targets, it is unclear whether this behavioural masked hidden repetition priming is also driven by Chinese phonology.

The hidden repetition priming observed in English originates from the activation of L1 (Chinese) and can therefore only occur when both the L2 (English) prime and L2 target are translated into L1 (Zhang et al., 2011). The activation of translations is consistent with the assumption of non-selective lexical access (e.g., Dijkstra, 2005; Dijkstra & van Heuven, 2002; van Heuven, Dijkstra, & Grainger, 1998). However, the L2 primes in Zhang et al. (2011) were presented very briefly (59 ms). Therefore, it is remarkable that the L1 translations of the L2 primes were activated because masked priming studies using non-cognate translation equivalents with similar prime durations have found strong L1-L2 (L1 primes and L2 targets) translation priming effects, whereas L2-L1 (L2 primes and L1 targets) translation priming effects have been found to be much smaller (but still significant, for a recent meta-analysis see Wen & van Heuven, 2017a). This translation asymmetry has been explained in terms of different strengths between lexical and semantic links for L1 and L2 (Kroll & Tokowicz, 2001) or slower activation of L2 representations (Allen, Conklin, & van Heuven, 2015), but it can also be attributed to a representational asymmetry between L1 and L2 words, with L1 words connected to more semantic features than L2 words (Finkbeiner, Forster, Nicol, & Nakamura, 2004; Schoonbaert, Duyck, Brysbaert, & Hartsuiker, 2009). In all cases, it seems unlikely that a translation asymmetry would occur if L2 primes would quickly activate the L1 translations as in Zhang et al. (2011). The activation of L1 translations by briefly presented L2 primes has not been observed in masked translation priming studies using ERP, because N250 effects (associated with translation form activation) were found for L1-L2 priming, but not for L2-L1 priming (e.g., Hoshino, Midgley, Holcomb, & Grainger, 2010; Midgley, Holcomb, & Grainger, 2009). Thus, the findings in the literature seem to indicate that masked L2 primes do not activate their L1 translation forms. It is also remarkable that the 75 ms hidden repetition priming effect observed in Experiment 1 of Zhang et al. (2011), which required the translation of L2 primes into L1, is similar in size to the L1-L2 translation priming effect reported in other masked priming studies with Chinese-English bilinguals (i.e., a mean priming effect of 69 ms from 4 experiments: Chen, Zhou, Gao, & Dunlap, 2014, Experiment 2; Jiang, 1999, Experiment 1; Xia & Andrews, 2015, Experiment 1B and 2B). Thus, it is crucial to further investigate the hidden repetition priming in the masked priming paradigm.

The present study aimed to further investigate hidden repetition priming in the masked priming lexical decision task and to determine the source of the hidden repetition priming effects observed by Zhang et al. (2011). To investigate whether Chinese phonology or orthography drives hidden repetition priming, Experiment 1 compared English word pairs with repeated characters (repeated orthography and phonology) in their Chinese translations and English word pairs with only repeated phonology in their Chinese translations. If hidden repetition priming is driven only by Chinese phonology, a priming effect would be expected for English word pairs with repeated phonology when translated into Chinese. This priming effect would be comparable to the priming effect for English word pairs with repeated characters in their Chinese translations. Alternatively, if hidden repetition priming is not driven by Chinese phonology, a priming effect would *only* be expected for English word pairs that have translations with repeated Chinese characters. To test whether the results favoured the null hypothesis (no priming effect) or the alternative hypothesis (a priming effect), the Bayes factor (BF) was also calculated by the BayesFactor package in R (Morey & Rouder, 2016). A BF smaller than 0.3 provides support for the null hypothesis and a BF larger than 3 provides support for the alternative hypothesis, whereas a BF between 0.3 and 3 supports neither hypothesis, which would indicate insensitive data (Dienes, 2014).

Experiment 1

Methods

Participants

33 Chinese-English bilinguals participated in Experiment 1. One participant was excluded because of high error rates in the experimental trials (> 25%). In this experiment as well as in the following experiments, the bilingual participants were all native Mandarin Chinese speakers who learnt Chinese from birth. Participants were undergraduate or postgraduate university students studying in Nottingham. They met the minimum English language entry requirements to study at the University of Nottingham (IELTS 6.0 for undergraduates and 6.5 for postgraduates). The details of participants' language background are summarized in Table 1.

Table 1
Summary of participants' language background data from 3 experiments.

	Mean (SD)		
	Experiment 1	Experiment 2	Experiment 3
Age (years)	22.5 (2.7)	21.2 (1.3)	22.8 (2.2)
Age exposed to formal English education	9.3 (2.2)	8.2 (1.8)	8.4 (2.8)
Time studies English (years)	13.2 (2.4)	13.0 (2.1)	14.1 (3.1)
English immersion experience (months)	6.2 (10.9)	4.0 (3.7)	9.0 (12.3)
Self-rated English Reading ability	4.9 (1.0)	5.3 (0.8)	5.1 (0.8)
LexTALE test score	62.7 (8.0)	62.3 (9.4)	63.5 (8.3)

Note. LexTALE (Lemhöfer & Broersma, 2012) is a quick and valid English vocabulary test; subjective reading ability were rated on a 7-point scale (1 = very poor, 7 = native-like). Results of Mann-Whitney Test showed that there was no significant difference in the self-ratings between participants from across 3 experiments ($p > 0.25$) and independent t-tests on their LexTALE scores also revealed no significant difference between the participant groups ($p > 0.25$).